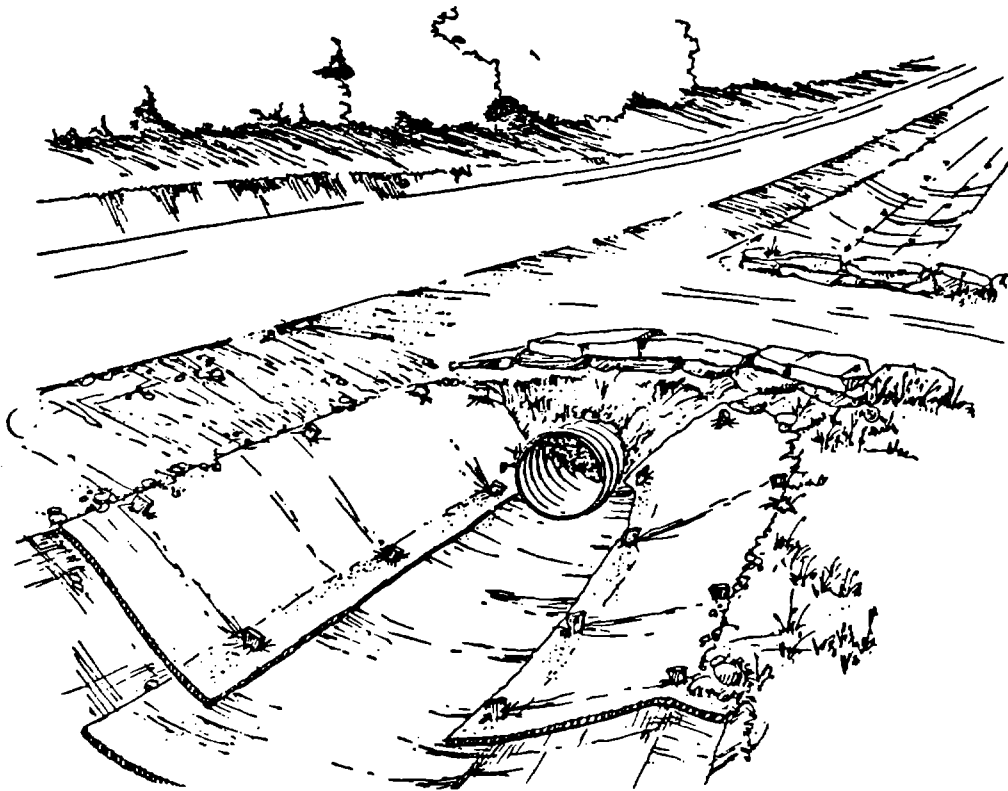


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ENKAMAT®

SOIL EROSION MATTING

EROSION CONTROL INSTRUCTION MANUAL



**MIDWEST CONSTRUCTION
PRODUCTS CORPORATION**

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ENKAMAT® MATTING
TECHNICAL MANUAL
FOR SOIL
EROSION CONTROL
APPLICATIONS

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PREFACE

This text is designed to be an instruction manual and to serve as a source of information related to the utilization of ENKAMAT® MATTING. The contents consist of a general coverage describing this unique geomatrix material its applications, SUGGESTED design approaches, and installation techniques.

Primary areas of concern are those dealing with EROSION CONTROL, LAND RECLAMATION and DRAINAGE, subterranean as well as surface.

ENKAFILTER™ Engineering fabrics are briefly discussed since, in several applications, they are used to form composite structures with ENKAMAT MATTING.

Diverse installation designs are presented to suggest methods for approaching general applications. However, it is STRESSED that these designs are NOT NECESSARILY OPTIMUM for all sites, and it is recommended that the design engineer modify them to fit his specific project and/or improve on them as necessary.

The appendix contains information that we feel will be beneficial to the reader who has little or no experience with geotextile applications. A short discussion of the Manning equation and a glossary of definitions relating to the practice of erosion control disciplines is included for the benefit of the beginning sales engineer. Some do's and don'ts, based on actual experiences, are also brought to the attention of the reader, especially so to the project design engineer and the installation contractor.

ENKAMAT® Disclaimer

We believe the information contained herein to be reliable and accurate for applications of ENKAMAT matting for erosion control. Since conditions vary with each site, however, Akzo Industrial Systems Co. makes no guarantee of results and assumes no obligation or liability for such results, the suitability of the material or the information contained herein for the use contemplated, unless specifically made in writing by Akzo Industrial Systems Co., or for safety or other damages occurring in connection with any installation. Furthermore, Akzo Industrial Systems Co. liability under any claim shall be limited to the cost of the ENKAMAT materials or replacement thereof, at Akzo Industrial Systems Co. option. This publication is not a license under which to operate and is not intended to suggest infringement upon or use or any existing patents or trademarks.

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SECTION I
INTRODUCTION

A. Material Description

1. ENKAMAT® Matting

A geotextile fabric made from nylon 6 monofilaments which are fused at their intersections to form a 3-dimensional matrix is specifically designed for erosion control and earth reinforcement applications. It is a bulky but very open structure with about 80% to 90% of its volume void, depending on desired density for specific use. The nylon contains 2% by weight carbon stabilizer to protect it against U.V. degradation.

The matrix form (Figure 1a) has been optimized for hydrodynamic energy dissipation and tensile properties made to meet load requirements in recommended applications (Table 1).

Packaging of the ENKAMAT rolls has been designed to facilitate handling in shipping, storage, and installation (Figure 1b).

2. ENKAFILTER™ Engineering Fabric

A geotextile nonwoven fabric constructed from polyester fibers is chemically bonded and needle punched. It is water permeable with tensile properties to meet load and water filtration requirements when used for recommended applications (Table 1).

3. ENKAMAT/ENKAFILTER Composites

ENKAMAT and ENKAFILTER fabrics are combined to form composites as indicated (Figure 2). Usage of each type is indicated in the following sections. More complex composites are formed by filling the ENKAMAT with sand or other soils. Vegetative root growth through these composites contributes to the overall structures.

The composites are formulated as schematically depicted (Figure 2).

Figure 2

- a Basic Structure ENKAMAT (E)
- b Composite Structure ENKAMAT/ENKAFILTER (E-E)
- c Composite Structure ENKAFILTER/ENKAMAT/ENKAFILTER (E-E-E)

FIGURE 1 - THE ENKAMAT® MATTING



a. The 3-Dimensional Matrix



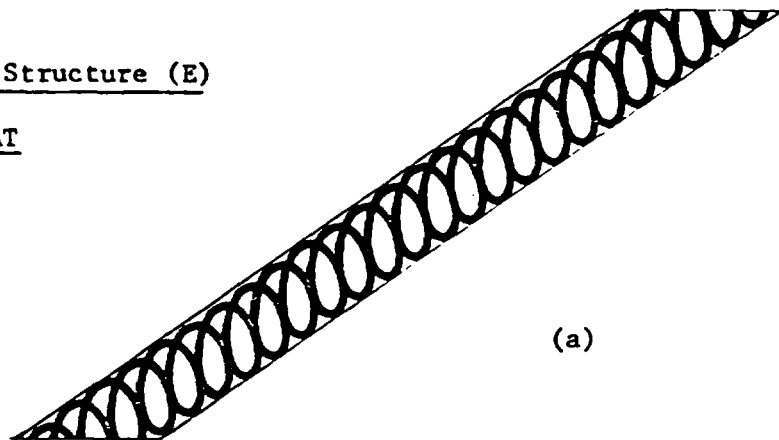
b. A Standard Roll

FIGURE 2

3-DIMENSIONAL ENKAMAT®/ENKAFILTER™ STRUCTURES

Basic Structure (E)

ENKAMAT

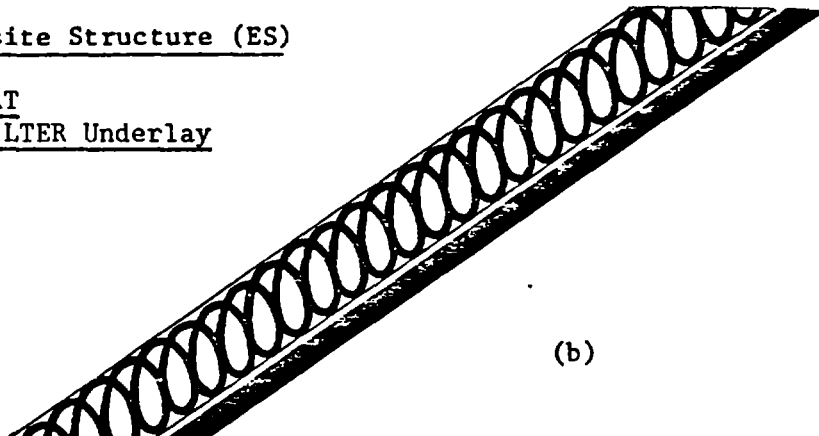


(a)

Composite Structure (ES)

ENKAMAT

ENKAFILTER Underlay



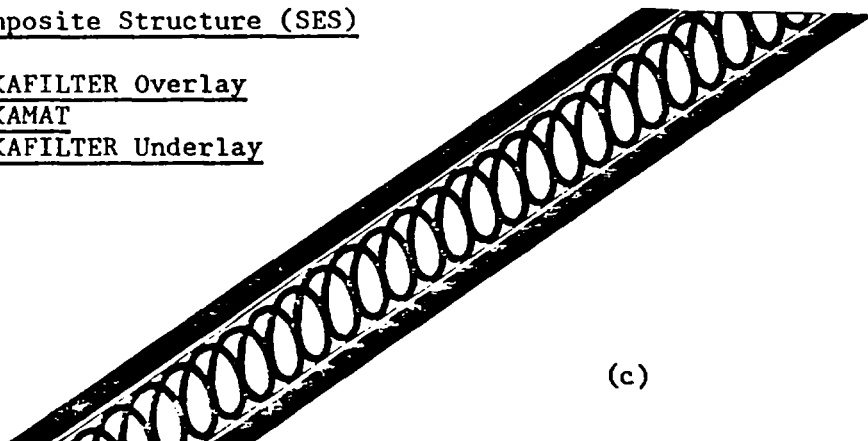
(b)

Composite Structure (SES)

ENKAFILTER Overlay

ENKAMAT

ENKAFILTER Underlay



(c)

ENKAFILTER™ ENGINEERING FABRICS

PROPERTIES AND DIMENSIONS	PROCEDURE	TYPICAL VALUES	
		E35	E43
Weight (oz/sq. yd)	(ASTM D3776)	3.5	4.3
Grab Strength (lb, MD/XD*)	(ASTM D4632)	130/85	90/100
Grab Elongation (% , MD/XD)	(ASTM D4632)	55/65	50/65
Trapezoid Tear Strength (lb, MD/XD)	(ASTM D4533)	40/30	30/40
Mullen Burst (PSI)	(ASTM D3786)	160	180
Puncture Strength (lb)	(ASTM D3787)	40	50
Flow Rate (gpm/sq. ft)	(ASTM D4491)	178	120
Coef. of Permeability (CM/SEC)	(ASTM D4491)	.22	.130
Permittivity (SEC ⁻¹)	(ASTM D4491)	2.38	1.62
AOS (US Series Sieve #1)	(ASTM D4751)	100-120	70/80
Roll Width (inches)		42/84**	43/86
Roll Length (Linear Yds)		750	750

* MD = Machine Direction
XD = Cross Machine Direction

** = Available on request

ENKAMAT® EROSION CONTROL MATTING

SPECIFICATIONS

(All Values Are Typical Unless Otherwise Stated)

<u>Type (ENKAMAT)</u>	<u>7010</u>	<u>7020</u>
-----------------------	-------------	-------------

Material: Nylon 6 Plus 2% by
Weight of Carbon Black

Dimensions:

Weight (oz/sq/yard)	8.0	12.0
Weight (oz/sq/yard) Minimum	7.3	11.1
Thickness (inches)	.4	.75
Width (inches)	38.5	38.5
Roll Length (feet)	492	328
Area (sq yds/roll) Minimum	173	116
Roll Gross Weight (lbs)	89	89
Filament Diameter (inches) Minimum	.014	.016

<u>Typical Physical Properties*</u>	<u>7010</u>	<u>7010</u>
-------------------------------------	-------------	-------------

Tensile Strength - Length (lbs/ft)	190	250
Tensile Strength - Width (lbs/ft)	55	120
Tensile Elongation - Length (%)	70	75
Tensile Elongation - Width (%)	80	75

Minimum Physical Properties*

Tensile Strength - Length (lbs/ft)	54	94
Tensile Strength - Width (lbs/ft)	27	54
Tensile Elongation - Length (%)	25	25
Tensile Elongation - Width (%)	25	25

Exposure (for 80% Strength Retention)

Temperature Range	-100° F to 250° F
pH Range	3 to 12

*ASTM 1682 Strip Test procedure modified to obtain filament bond strength used to indicate tensile properties of ENKAMAT matting.

Typical Physical Properties are representative of the product in a full width application. However, due to the geometry and randomness of the product, some test results may be below the typical values stated. However, all products will have values greater than the minimum stated above. Minimum average lot values are available upon request.

B. Functions

1. ENKAMAT® Matting

- a. Basically, the matting is designed to act as a reinforcing matrix for vegetative roots. Although there are specialized applications, such as reinforcing grout, asphalt linings, and cemented soils, ENKAMAT was initially developed to form a substrate for vegetation, where it forms a composite system consisting of the soil-filled matrix entangled and penetrated by roots which form a continuum of anchorage of the vegetative surface growth. The entire composite is a Root Reinforcing System (RRS) supporting an effectively anchored energy dissipator extending through above surface vegetation.

Additionally:

- b. Before vegetation develops, it:
 - (1) Protects surface against the weathering erosion of wind and rain.
 - (2) Prevents disturbance of seed distribution.
 - (3) Acts as water energy dissipator by creating a myriad of eddies in the lower strata.
 - (4) Causes silt dropout to fill matrix with fine soils which become the media for growth development of roots.
- c. After vegetation develops:

Embedded into the soil, ENKAMAT, as an integral part of the Root Reinforcing System (RRS), forms a tough surface cover skin which protects subsoils against erosive forces.

- (1) In channels, the RRS (Figure 3) resists HYDRAULIC LIFT and SHEAR forces created by high volume and high velocity runoffs. It prevents the isolation of individual roots and clumps by fine eddy turbulences that would eventually undermine the vegetation. Acting forces are distributed along the breadth and width of the RRS, preventing the isolated tearing out of grass clumps which would be caused by force concentrations.

- (2) On slopes as well as in channels, the strength of the matrix adds significantly to the tensile level of the root system. Indeed, it becomes almost the sole support of overloaded vegetative stands under water-saturated conditions as soil cohesion and root anchorage strengths approach minima.

2. ENKAFILTER™ Engineering Fabric

Although the ENKAFILTER also contributes to the tensile of composite system, its primary function is that of a filter layer which is permeable to water flow but prevents passage of fine soils.

This function will be clearly indicated in Section II where the varied applications are shown.

3. ENKAMAT®/ENKAFILTER Composites

Functions of the composites will also be readily apparent in Section II.

ENKAMAT® LINING IS EMBEDDED INTO SOIL TO
FORM TOUGH SURFACE SKIN COMPOSITE SYSTEM

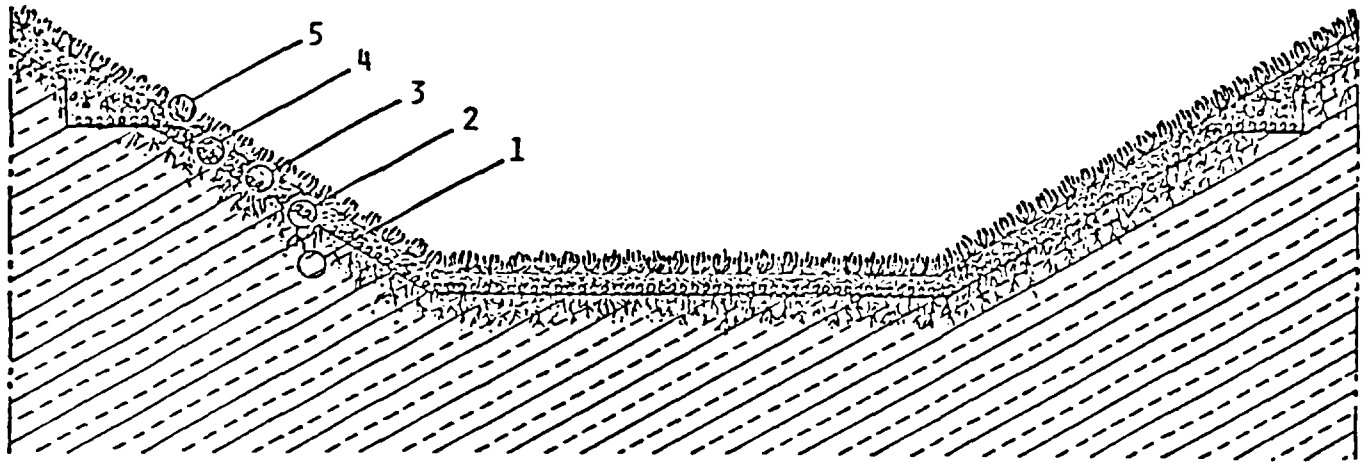


FIGURE 3 - IN CHANNEL

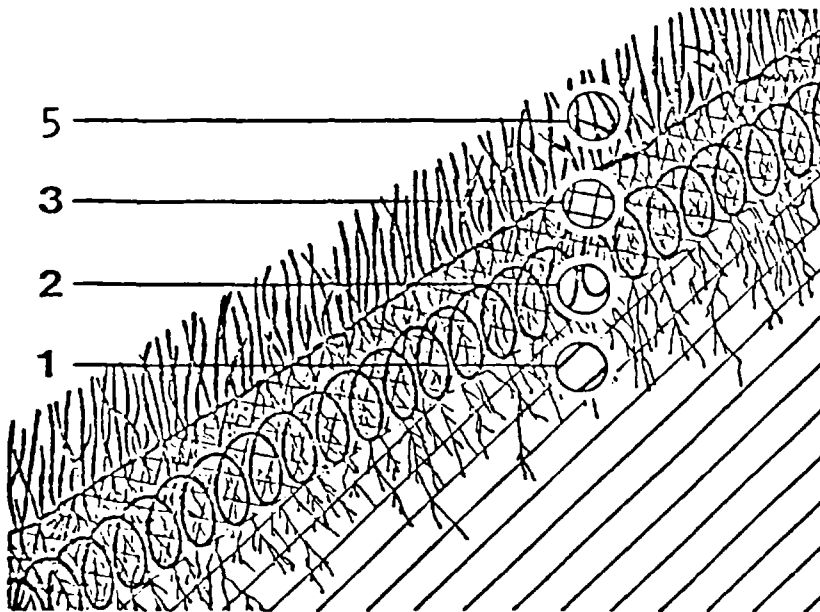


FIGURE 4 - ON SLOPE

- | | | |
|-------------|-------------------------------|---------------|
| 1. Subsoil | 2. ENKAMAT Reinforcing Matrix | |
| 3. Sediment | 4. Root System | 5. Vegetation |

SECTION II

APPLICATION AND DESIGN APPROACHES

The following sketches are presented to suggest ENKAMAT® applications and related design approaches. They are not to be construed as an exact engineering specification for any or all problem sites. The responsibility for design of a particular project ultimately lies with the design and/or construction engineers.

However, since the methods covered herein are based on considerable experiences, including careful studies of failure modes and corrective measures, it is recommended that both project engineers and installation contractors give serious consideration to them. We also encourage the reader to study each design, looking toward improving or modifying them.

The sketches are indicative of methods to be used. Installation details are given in Section III.

A. Channels

1. Shallow Roadside Ditch (Figure 5)

These are usually low-velocity, low-volume channels with triangular or parabolic cross sections. Quite often seen in residential areas, they may contain culverts underlaying side roads or streets.

If water is anticipated to sheet off of side road into ditch, the upper and side slopes should be protected and the culvert collared with ENKAMAT®. Otherwise, the ENKAMAT can be tucked under culvert terminals.

2. Highway Ditches (Figure 6)

Typical of interstate systems, these channels are designed to carry relatively high volumes of water at high velocities. They are usually constructed with parabolic or trapezoidal cross sections.

When encumbered with culverts, input and output aprons are usually present. The ENKAMAT can be readily joined to these.

3. Converging Channels (Figure 7)

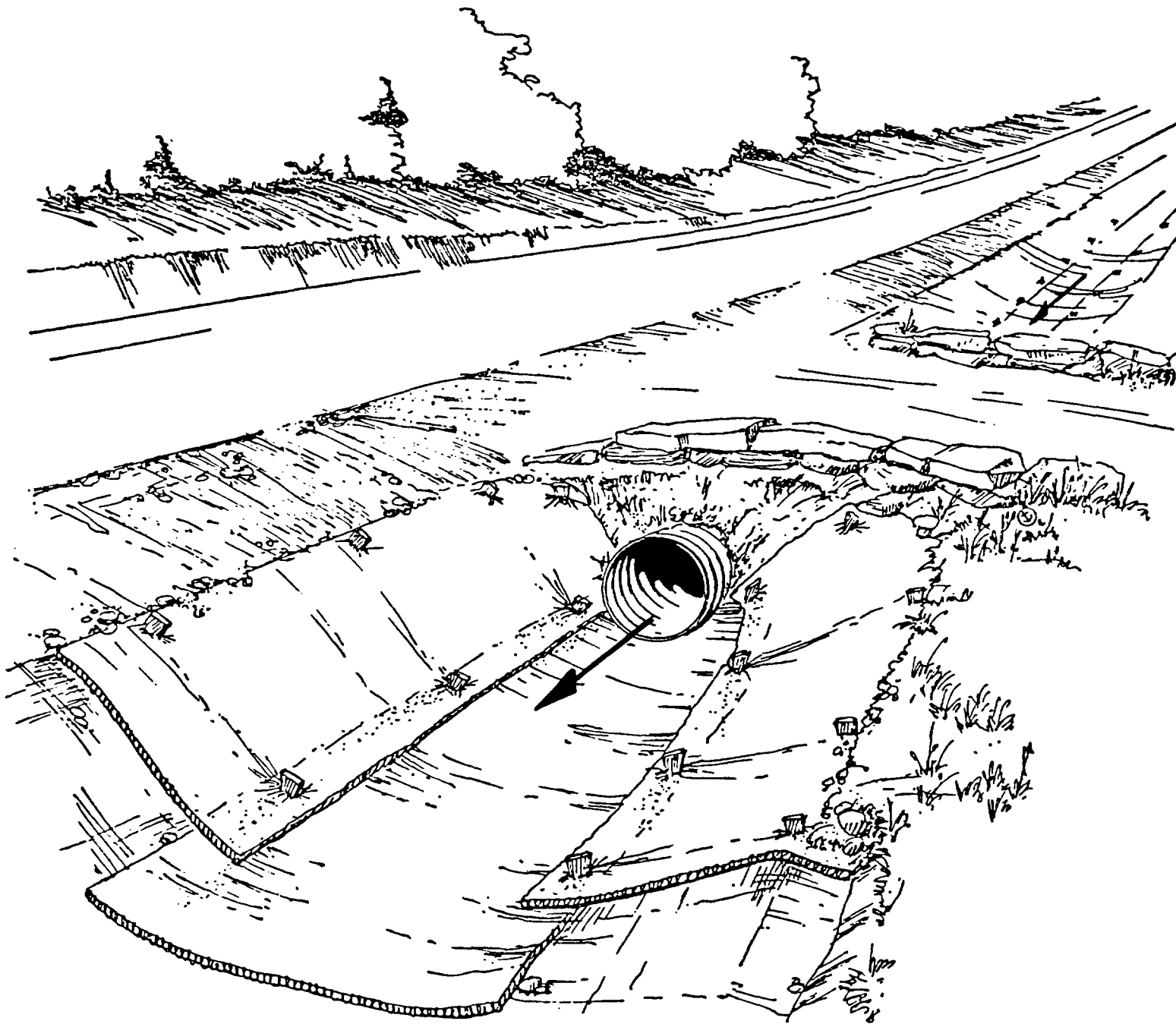
A side channel feeding into a main channel is usually of parabolic cross section. When one or more side channels are in a feeder network, they should be lined with ENKAMAT before the main run-off channel is covered. The ENKAMAT lining of the side channel should be extended out and across the main channel so that it acts as an underlay to and reinforces the main channel in the proximity of the junction.

4. Storm Channels (Figure 8)

Typical storm channels commonly have trapezoidal cross sections with wide, flat bottoms and steep, high-sided banks. They are designed to carry off high volumes of water from urban and/or suburban areas as well as from highly-developed residential, recreational, and commercial zones. They are prominent in regions frequented by cloudburst or monsoon-type rainfalls.

FIGURE 5 - ENKAMAT® CHANNEL LINING - SHALLOW ROADSIDE DITCH

(LOW VOLUME)

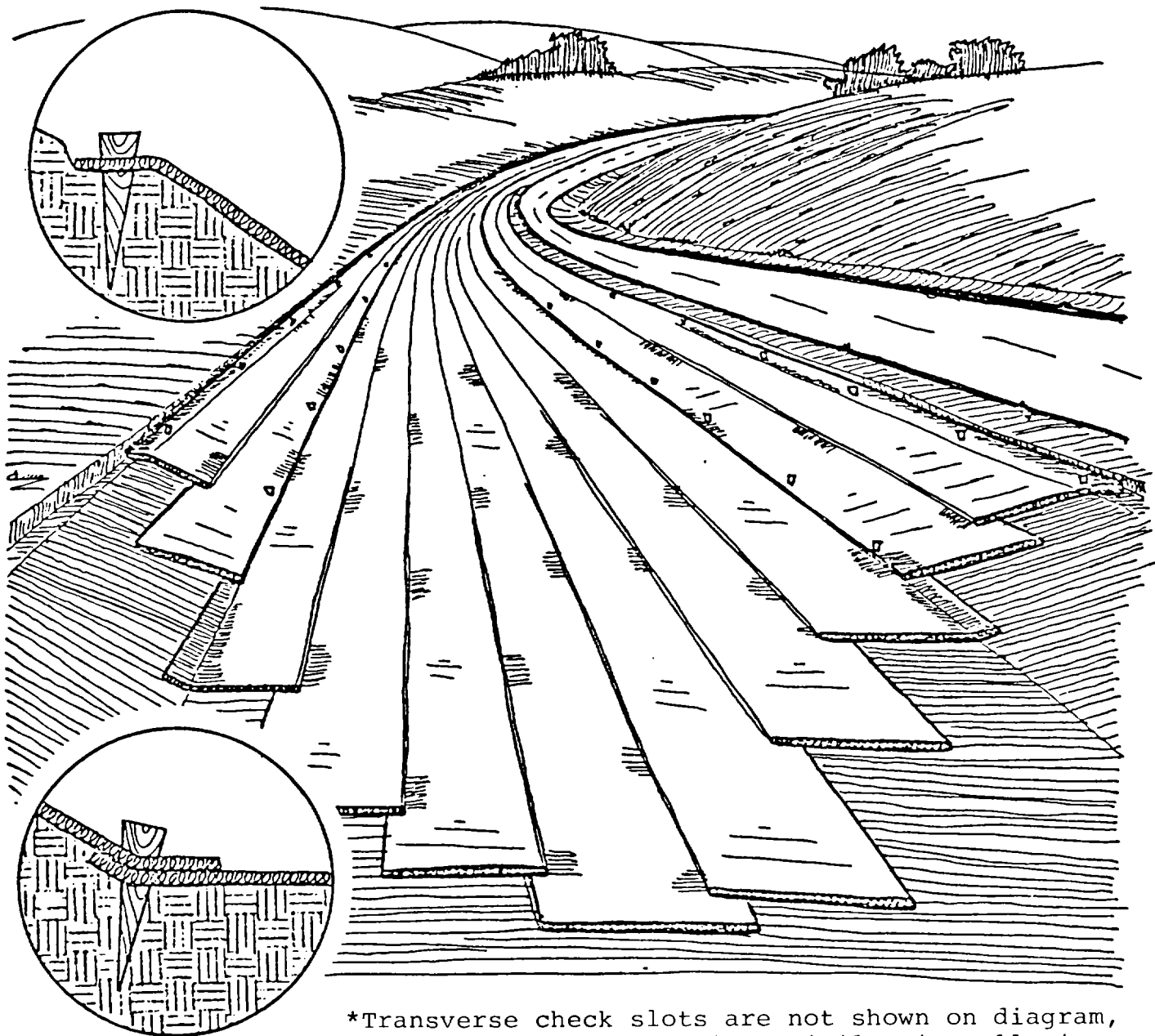


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FIGURE 6 - ENKAMAT® CHANNEL LINING - HIGHWAY DITCH*

(HIGH VELOCITY - HIGH VOLUME)



*Transverse check slots are not shown on diagram, but would be required in a similar installation. See pages 37 and 45.

FIGURE 7 - ENKAMAT® CHANNEL LINING - JUNCTION OF CONVERGING CHANNELS

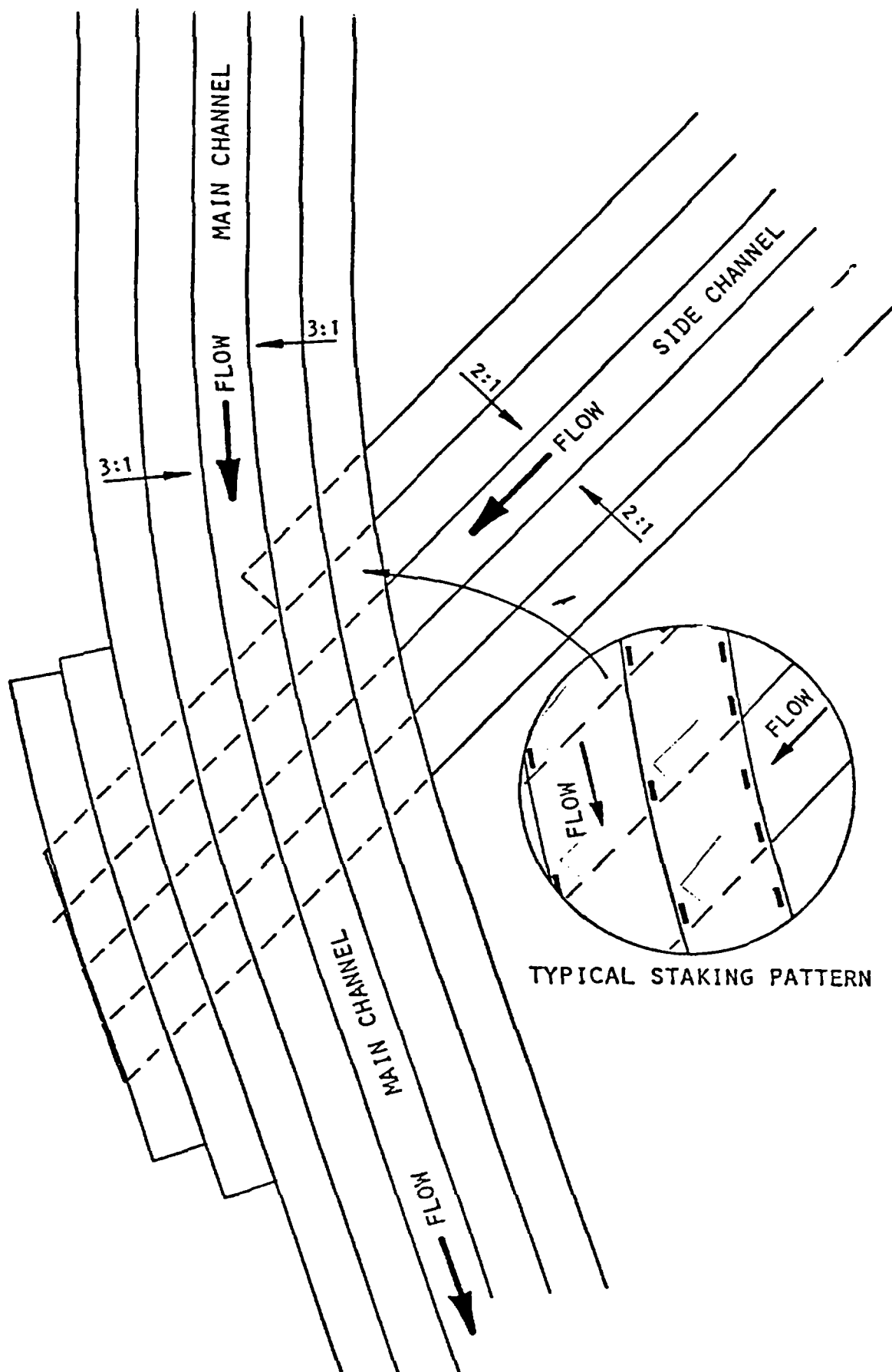
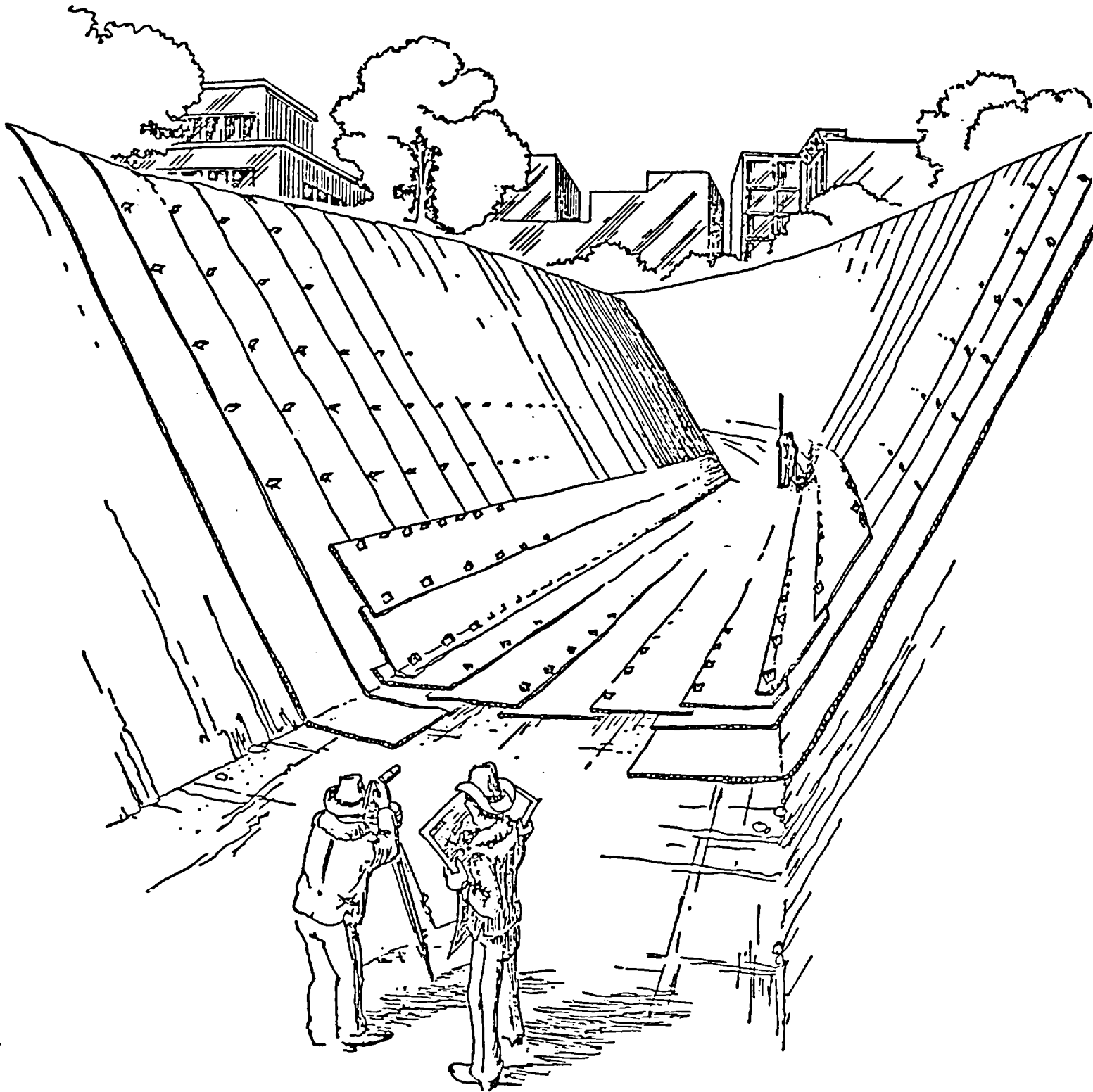


FIGURE 8 - ENKAMAT® CHANNEL LINING - STORM CHANNEL

HIGH VOLUME



B. Banks and Slopes

Although similar, BANKS are distinctive from slopes. For clarity, a BANK is considered to be a SLOPE that borders and/or contains a waterway, whether it be a running stream, pond, lake, or other hydrous body. This includes the slopes of normally dry as well as continuously flowing channels and empty or full basins.

In any case, there are instances when banks must be treated differently from ordinary slopes. However, there are design and installation approaches common to both.

In shallow channels, ENKAMAT® may be installed on side slopes running laterally; i.e., parallel to the bottom. However, when channel depths exceed 5', it is stressed that ENKAMAT should be dropped vertically downslope. DO NOT run ENKAMAT horizontally along deep channel side slopes.

Specific installation procedures are covered in Section III.

1. Channel Banks

a. Scour Bottom Channel Banks--Normally Dry (Figure 9)

- (1) ENKAMAT is dropped downslope and extended onto channel bottom for 3'-5'. ENKAMAT need not be buried into slope toe.
- (2) Bottom of channel is then lined with longitudinal runs of ENKAMAT extending upslope for about 1.5 to 2 widths. This affords a double thickness of ENKAMAT cover at the vertex at the channel edge where scour forces are greatest.
- (3) Where erodible soils (sand, silt) are encountered, it is recommended that an underlay of ENKAFILTER™ fabric be installed (see inset of Figure 9). Particular attention should be paid to this at the outside bends of channels.

b. Deposition Bottom Channel Banks--Normally Dry (Figure 10)

- (1) ENKAMAT should be dropped vertically downslope and toed into channel bottom.
- (2) Two to three widths of ENKAMAT should run laterally along toe to overlay and reinforce the vertical drops against shearing force.

- (3) When encountering erodible soils, the ENKAMAT® should be underlaid with ENKAFILTER™ to protect channel bottom vertex against scour.

c. Berm Drop Swale (Figure 11)

- (1) In this specialized case when storm waters are being dropped from a berm into a deep channel, the banks are first lined as previously indicated. However, to concentrate the runoff, a shallow depression should be shaped to form a swale extending over the berm edge and downslope.
- (2) A culvert output channel on a berm is also lined with ENKAMAT extending onto and overlapping the bank lining.

d. Flood Control Bank (Figure 12)

There are many situations where a stream normally meanders through a relatively broad depression, having what may be considered a stabilized vegetated "flood plain" between it and a steep escarpment leading to higher ground levels. However, when the area is flooded, this escarpment then becomes a storm channel bank.

To prevent progressive undercutting of this escarpment, the design approach of Figure 12 is suggested.

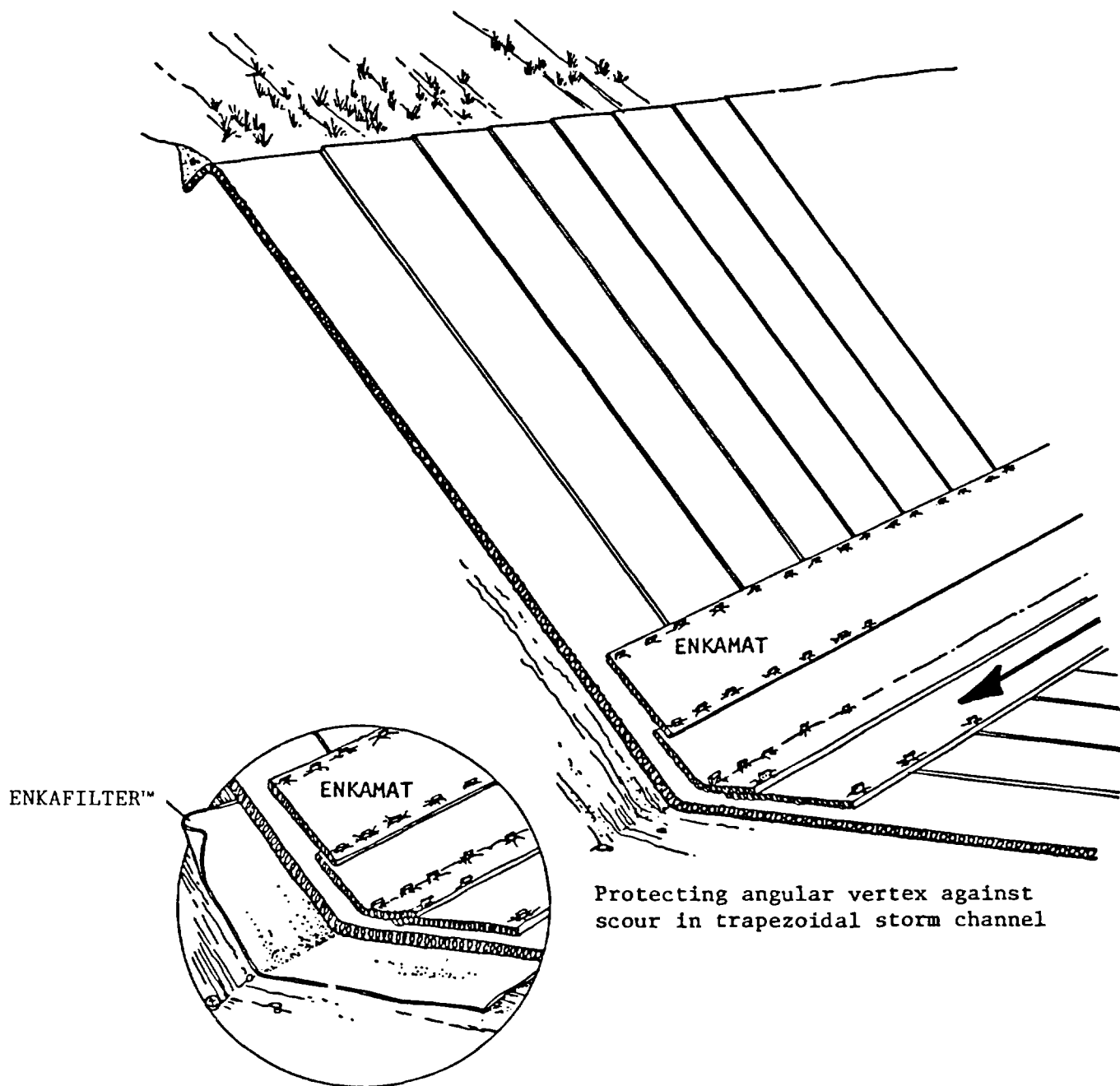
An ENKAFILTER underlay is first laid parallel to the slope with the bottom edge toed in and the upper edges reaching about 5'-6' upslope. The ENKAMAT is then dropped downslope overlaying the ENKAFILTER into the toe trench. Depending on the anticipated depths and water velocities, the backfilled toe trench may be firmed with riprap extending upslope for about 3'. Where slope soil is erosion resistant, the riprap is not necessary.

Note

- (1) ENKAMAT should be covered with 1" soil where it is underlaid with ENKAFILTER.
- (2) The ENKAFILTER allows water to seep out of saturated bank without fine soil loss when flood waters recede.

FIGURE 9 - ENKAMAT® BANK LINING - BOTTOM LINED CHANNEL

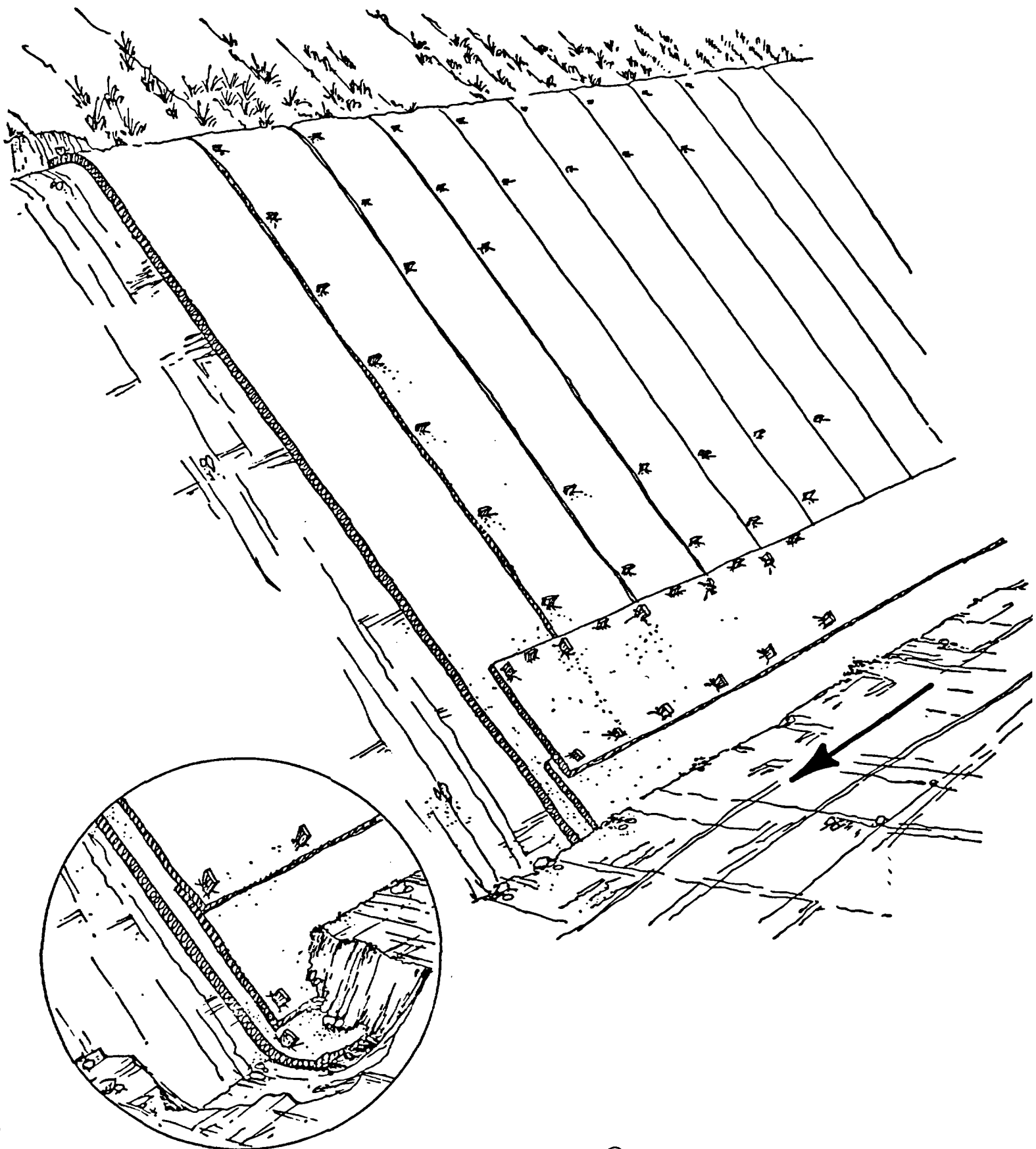
(REINFORCED TOE CONSTRUCTION)



Protecting angular vertex against
scour in trapezoidal storm channel

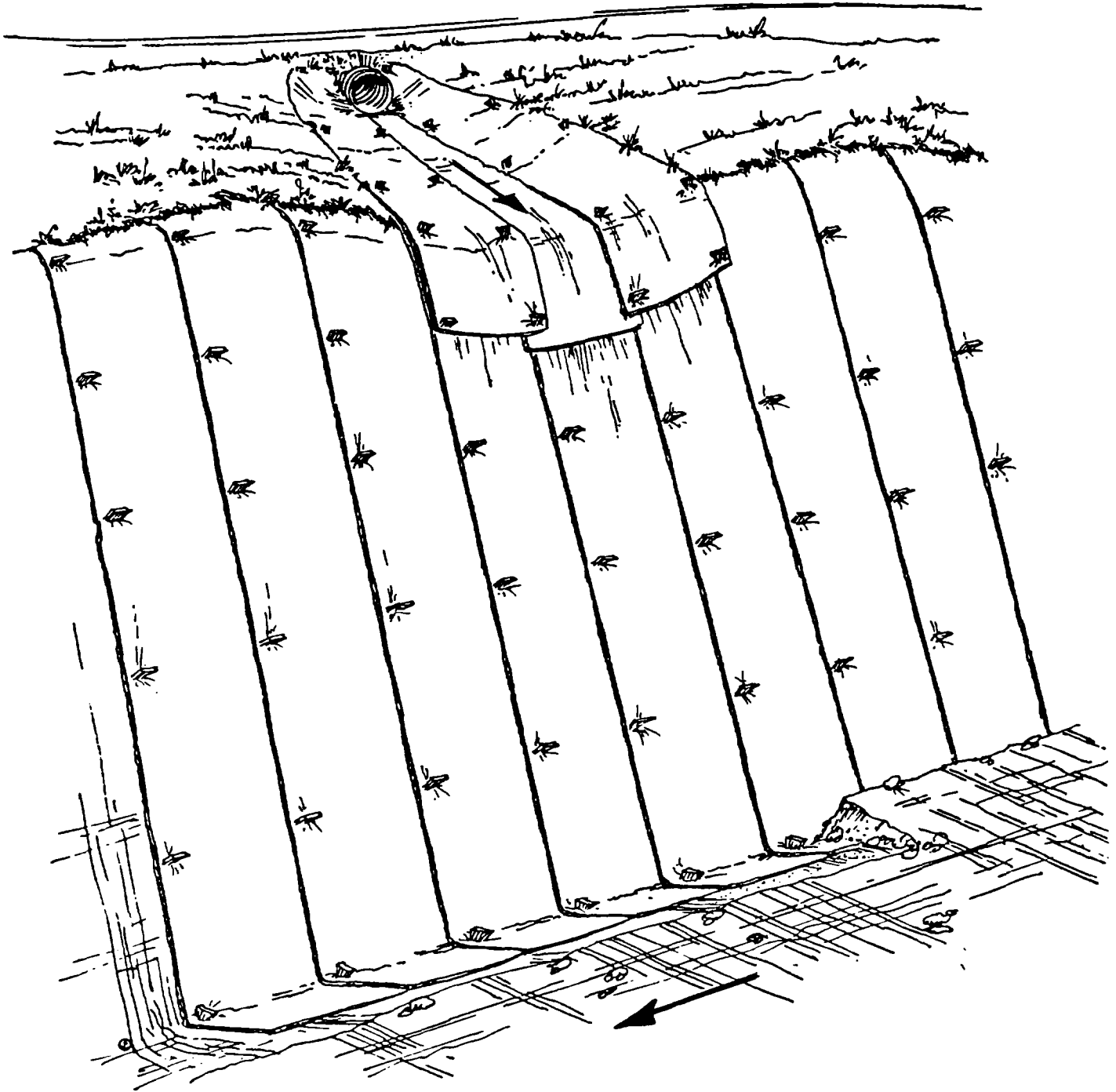
FIGURE 10 - ENKAMAT® BANK LINING - BARE BOTTOM CHANNEL

(REINFORCED TOE CONSTRUCTION)



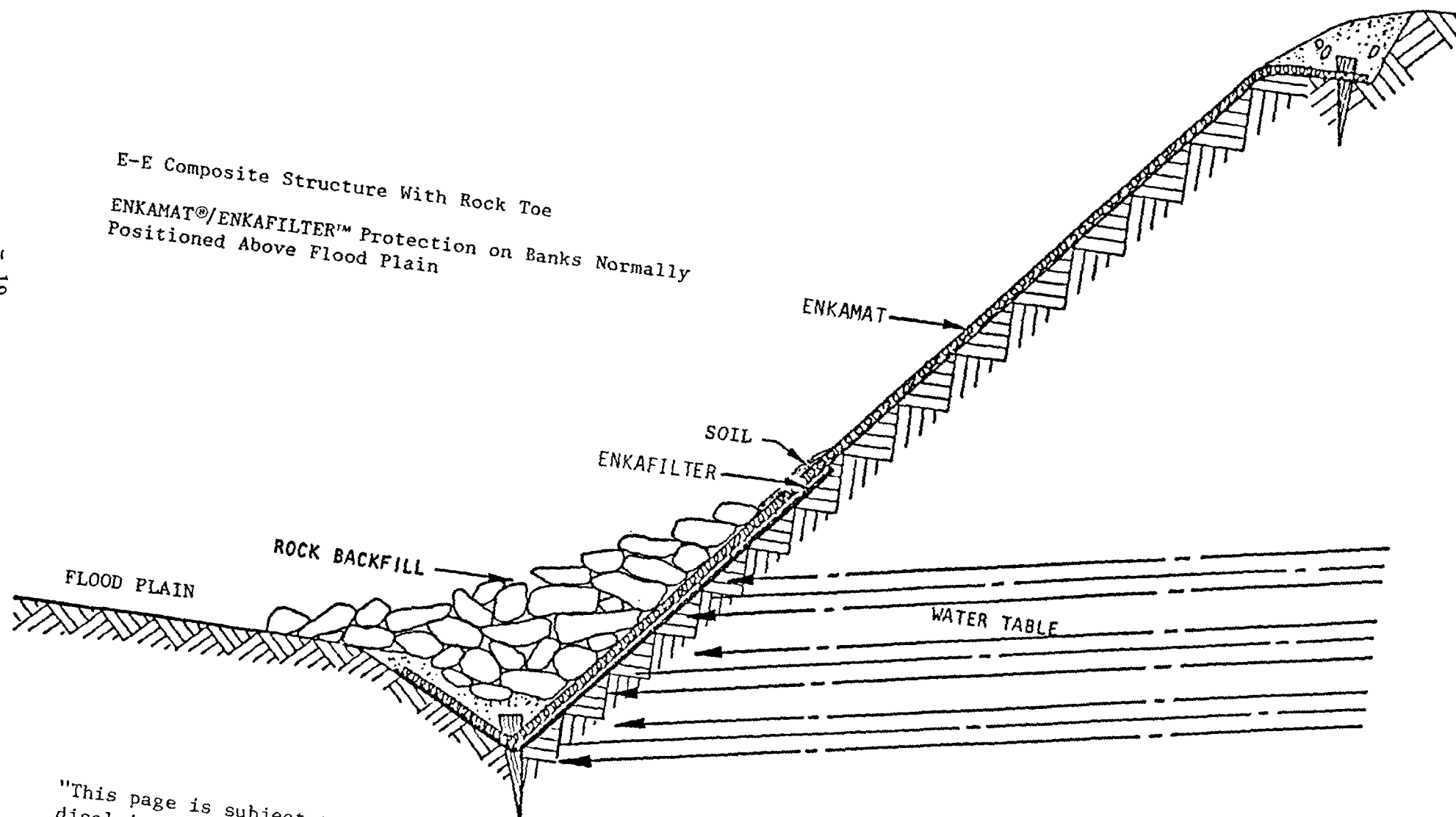
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FIGURE 11 - ENKAMAT® LINING - BERM DROP



Culvert Output Channeled Off of High Berm

FIGURE 12 - BANK PROTECTION - FLOOD CONTROL BANK
(REINFORCED TOE CONSTRUCTION)



E-E Composite Structure With Rock Toe
ENKAMAT®/ENKAFILTER™ Protection on Banks Normally
Positioned Above Flood Plain

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2. Slopes

Slopes, distinguished from waterway related banks, are typically observed alongside highways, edges of leveled building sites and similar locals. They may be either cut or fill slopes and may be situated on dry, subterranean bases or over water seepage sites stemming from rain-saturated soils or ground water lens formations.

a. Typical Dry Slope (Figure 13)

Vertical ENKAMAT® drops from berm to the trenched toe and, properly staked, forms a sufficient design for most slopes (either fill or cut).

b. Wet Slopes

When constructing storm channels along roadways or leveling a development site in rolling hill or mountainous country, it is not uncommon to cut into an aquifer lens formation with resulting water bleeding out of the right-of-way bank. This water carries soil aggregates out of the formed slopes. The loss of this soil undercuts support for the upper slopes and they eventually cave in. The following designs offer some preventative measures.

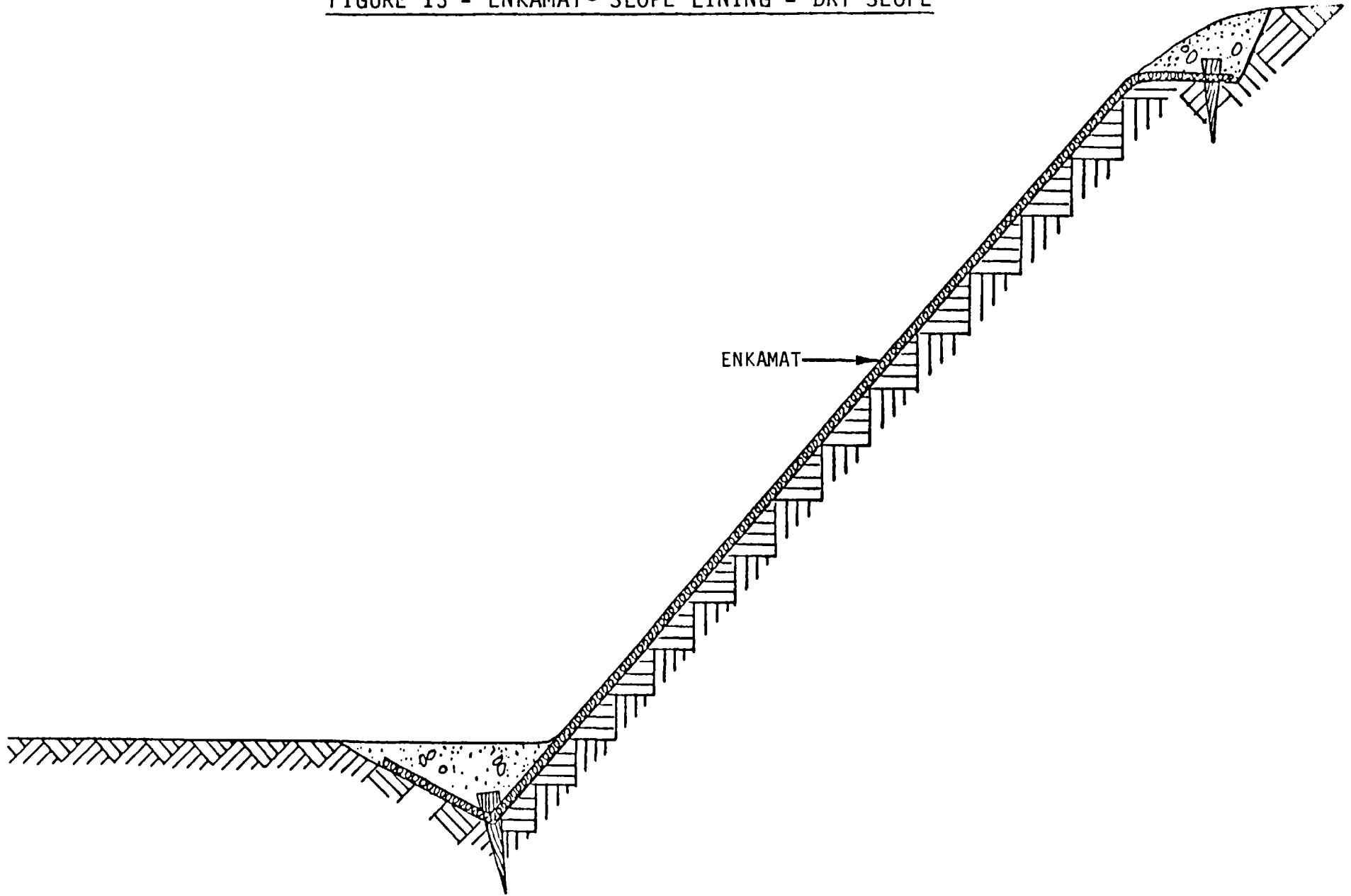
When experiencing seepage from rain-saturated soils or aquifer lens formations (Figure 14) underlay bottom portion of ENKAMAT slope lining with ENKAFILTER™. ENKAFILTER should be run laterally along lower slope. Bottom edge of ENKAFILTER is tucked into toe trench. Upper edge extends up slope about 1' above wet line.

ENKAMAT portion which is underlayed with ENKAFILTER must be covered with about 1" of soil media to enhance root development.

3. Aquifer Slopes

When cutting rights-of-way through rolling terrain or foothills or when terracing slopes, it is likely that you will cut into an aquifer. One or more of 3 destabilizing situations may develop as the natural overburden is removed during shaping.

FIGURE 13 - ENKAMAT® SLOPE LINING - DRY SLOPE



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- (a) Water bleeding out of slope through lens formations (see Figure 14).
- (b) Concentrated movement of a mud slurry flowing out of a blow hole in the slope.
- (c) Migration of water due to capillary action seeping to the exposed surface.

a. Lens Seepage

This condition can be most easily remedied using the Figure 14 design approach using a soil plating over the seepage area. Conditions (b) and (c) can be brought under control using the following approaches:

b. Aquifer Slope Blowouts (Figure 15)

This condition occurs when an aquifer node is cut across. This usually forms a muddy slurry oozing out of the lower slope, which results in loss of support for the upper slope and eventually leads to "slump outs" which are progressive.

As long as the "instability" is limited to the slope, the blow hole can be simply capped using an E-E-E composed sandwich (Figure 15).

To remedy this situation, the unstable overburden is removed and localized area is shaped. A layer of ENKAFILTER™ is laid over the critical site, followed by a layer of ENKAMAT® which, in turn, is overlaid with ENKAFILTER. The capping fabric area should be extended well onto stable soil to achieve a firm anchorage. After properly staking the E-E-E cap, an overburden of soil is laid on it. The depth of the overburden should be sufficient to counter the pore pressure contained by the composite. No less than a 1' depth of compacted soil overburden is advised.

The underlying permeable ENKAFILTER allows water movement into the ENKAMAT whence it drops downslope to a drainage net. At the same time, it prevents soil fines from passing into and clogging the ENKAMAT. The overlying ENKAFILTER layer prevents the overburden soil from filling the ENKAMAT.

c. Aquifer "Blowout" and Bench "Boil" Formation (Figure 16)

In a terracing site, if an aquifer has been cut into in such a way that both slope and bench lie under the natural aquifer envelope, then hydraulic lift pressures can create "quick" or "boil" situations on the flat bench. This is an unstable condition that can readily become a mire, resulting from pumping action of any traffic passing over it.

Frequently, these "boils" are associated with slope "blowouts" and are indeed an extension of the same aquifer system. When this occurs, then the E-E-E composite layer can be extended to cap both the slope and the bench flows (Figure 16).

Where only a bench "boil" is experienced, the E-E-E composite need only be applied to it.

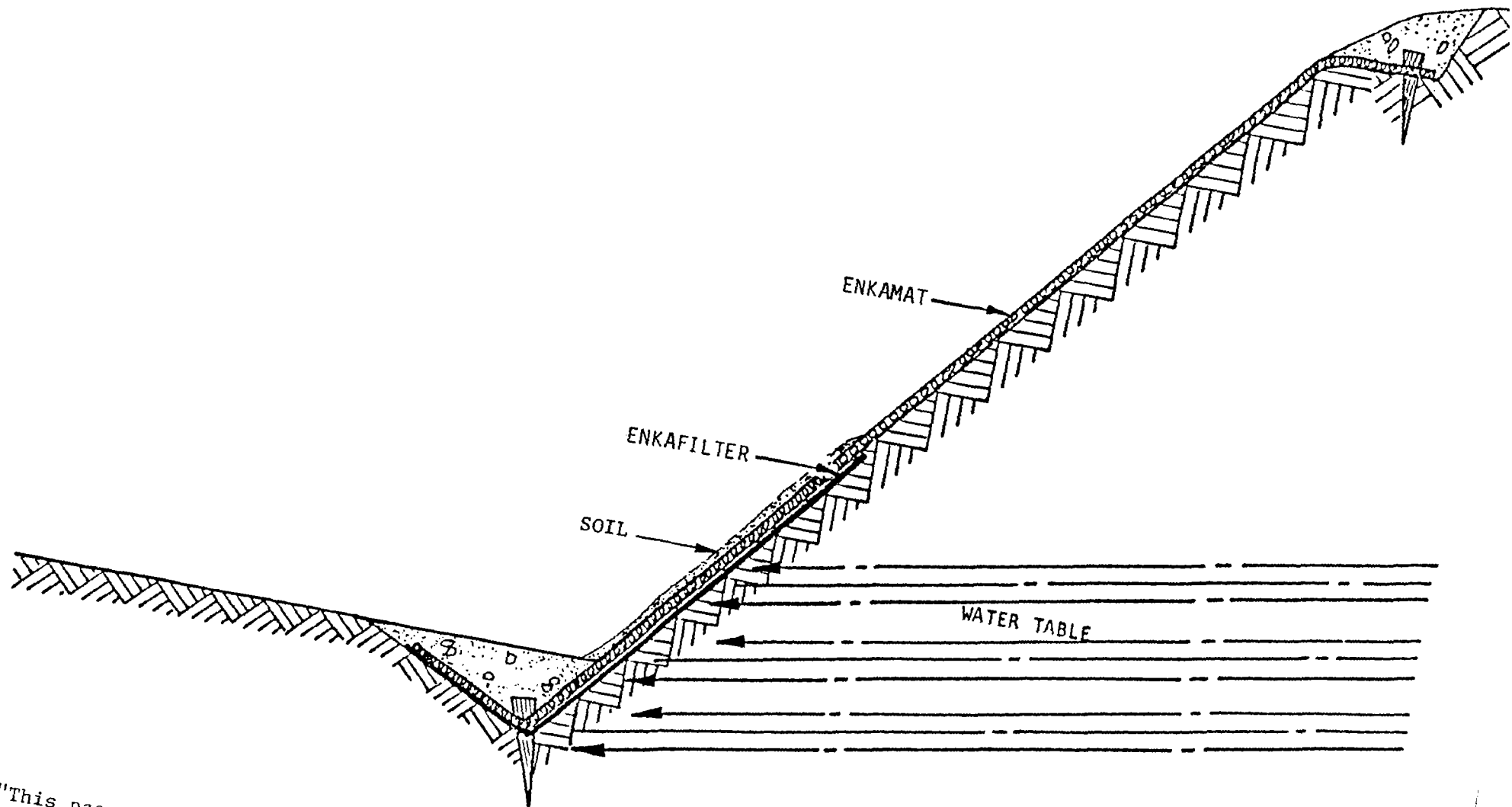
d. Acid Slopes

The movement of water through some highly mineralized deposits (for example, sulphur) will create extreme acid conditions in aquifers. When cuts are made through these, slope soils have such a low pH that they become intolerable to vegetation. These acid waters migrate usually toward slope cuts through clay soils by capillary action.

By removing a 1'-2' depth of contaminated soil and installing E-E-E layering in the manner previously indicated, the acid waters are intercepted and dropped into a subterranean drainage net (Figure 17). Covering the E-E-E composite with a minimum depth of 1' of uncontaminated soil permits revegetation of these sites. Where deep-rooted vegetation is desired, the depth of the E-E-E composite may have to be greater than 1'.

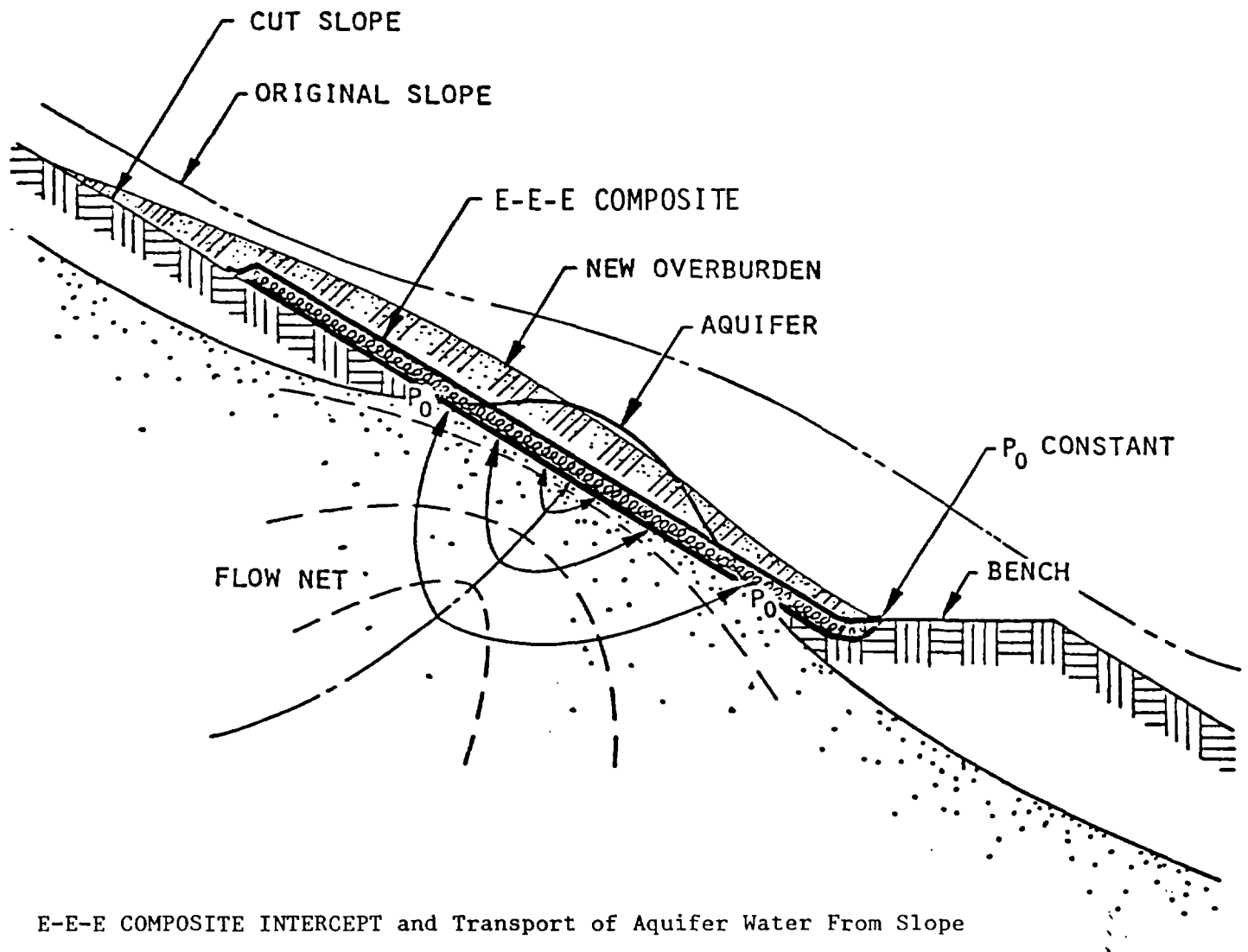
An alternate design for the disposal of acid water is to drop it into a concrete-lined channel (Figure 18) instead of the vegetated one depicted in Figure 17.

FIGURE 14 - ENKAMAT®/ENKAFILTER™ (EE) SLOPE LINING - WET SLOPE



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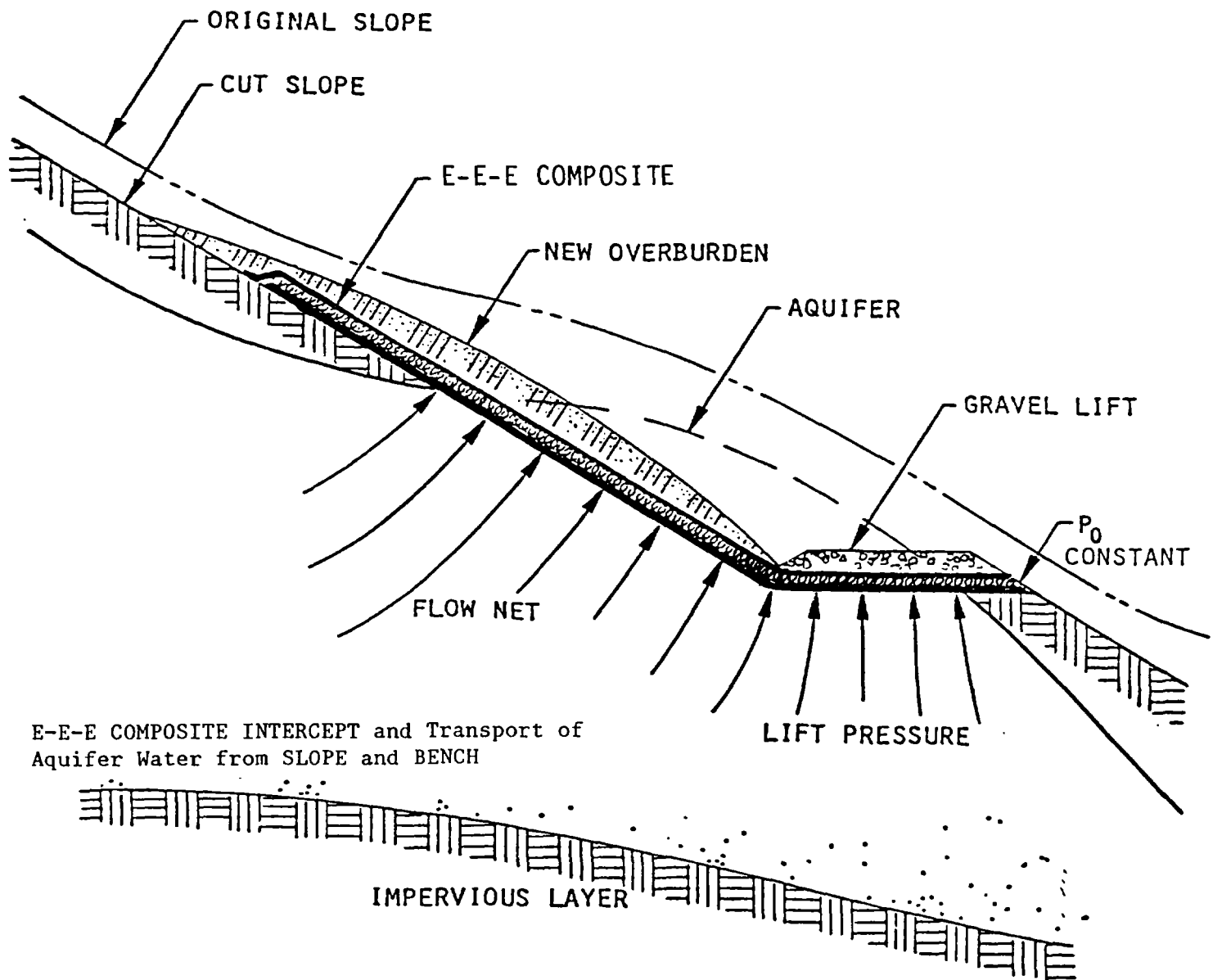
FIGURE 15 - E-E-E COMPOSITE STRUCTURE - CAPPING AQUIFER BLOWOUTS



E-E-E COMPOSITE INTERCEPT and Transport of Aquifer Water From Slope

FIGURE 16 - E-E-E COMPOSITE STRUCTURE - CAPPING AQUIFER

(SLOPE BLOWOUT AND BENCH SAND BOIL)



E-E-E COMPOSITE INTERCEPT and Transport of
Aquifer Water from SLOPE and BENCH

FIGURE 17 - E-E-E COMPOSITE STRUCTURE

ACID SLOPE AND CHANNEL STABILIZATION

(VEGETATED CHANNEL)

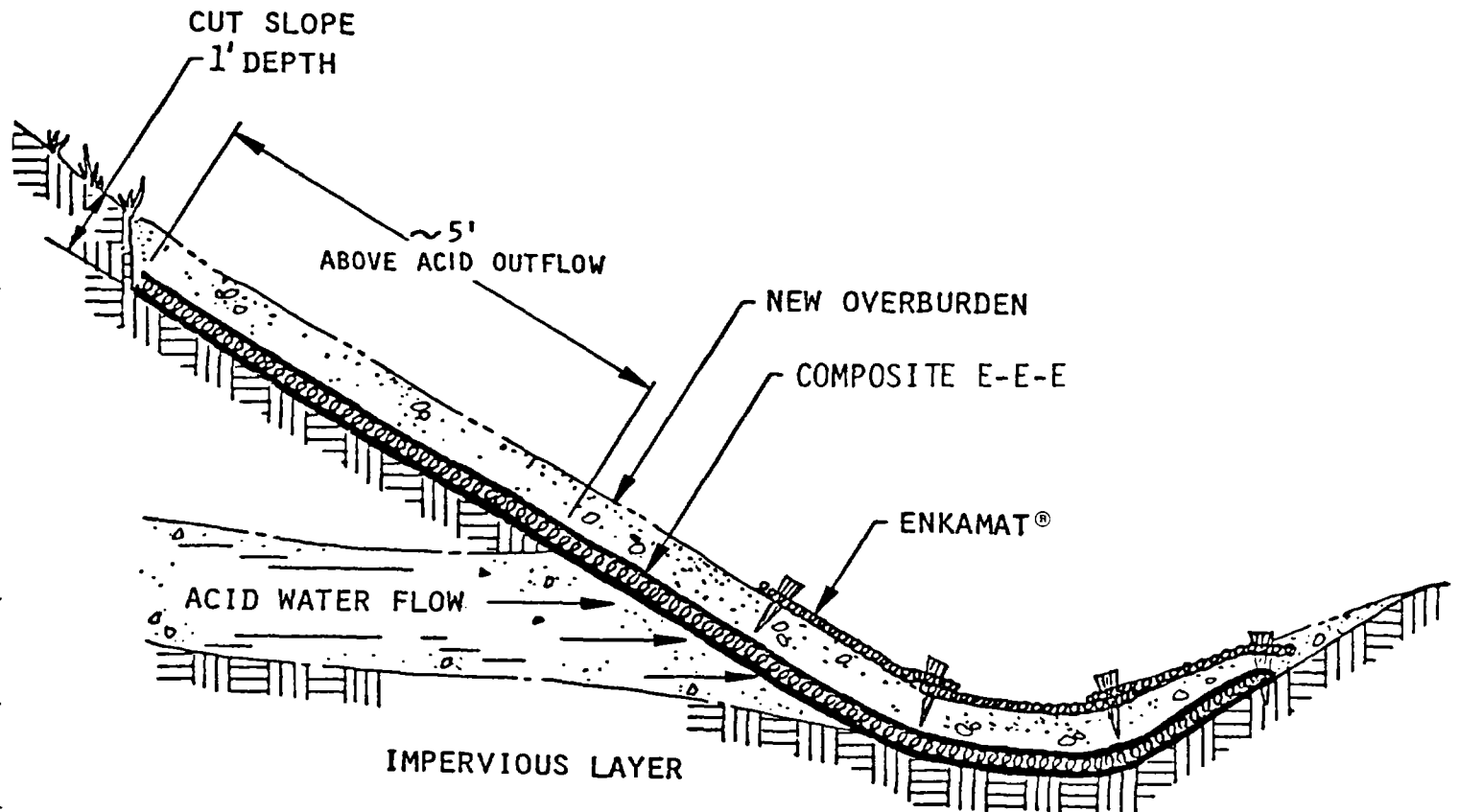
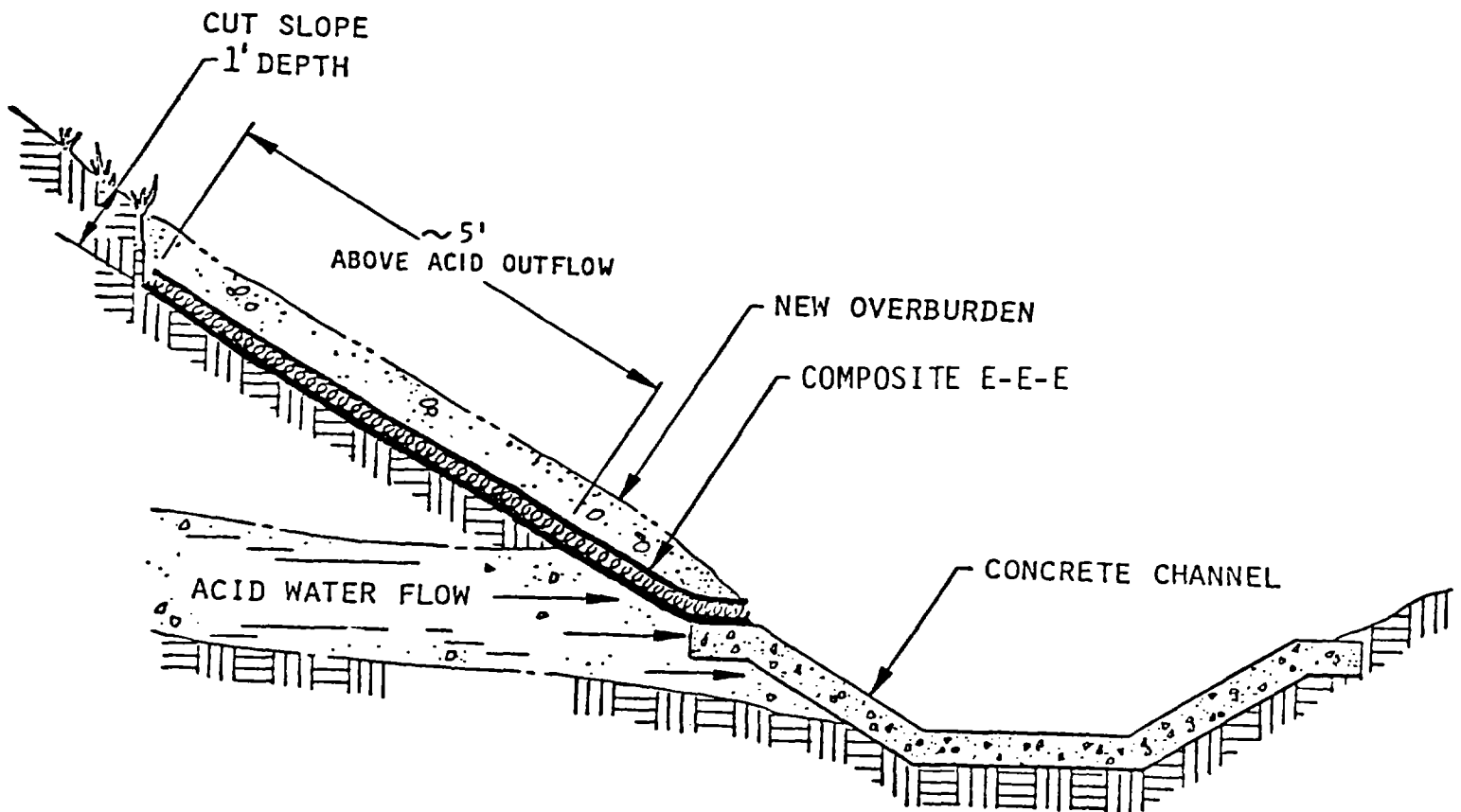


FIGURE 18 - E-E-E COMPOSITE STRUCTURE

ACID SLOPE STABILIZATION

(CONCRETE CHANNEL)



C. Shorelines

Preceding bank and slope designs can be readily modified to fit many shoreline protection requirements.

1. Low-Profile Waterway Walls

Boat traffic channels are frequently lined along their edges with a low-profile wall. These walls are usually constructed from concrete (Figure 19), rot-resistant wood (Figure 20) or rock riprap (Figure 21). These footing walls protect the bank toes against scour from boat wash, thus preventing saturated and softening bank soils from sliding into the channel. The terrain behind these walls may be either flat, which can be utilized for shoreline walk or driveways, or it may extend upward onto slopes of varied steepness using the walls for retention.

The low-profile walls are normally effective against the aforementioned factors. However, they are susceptible to wave action and boat traffic backwash which slops over and causes heavy erosion behind them.

When terrain is flat, the simple procedure of installing ENKAMAT® underlaid with ENKAFILTER™ along the wall prevents the spillover scour. The ENKAMAT, covered with 2" of topsoil and seeded or sodded, affords a well-protected, flat, grassy surface to form very effective walkways.

When steep banks form the terrain behind the walls, overlapping wave action erodes the slope toes, usually resulting in bank cave-in. The suggested designs of Figures 19, 20, and 21 afford protection against this.

FIGURE 19 - SHORELINE PROTECTION - STEEP WATERWAY BANKS

(LOW-PROFILE CONCRETE CHANNEL WALL)

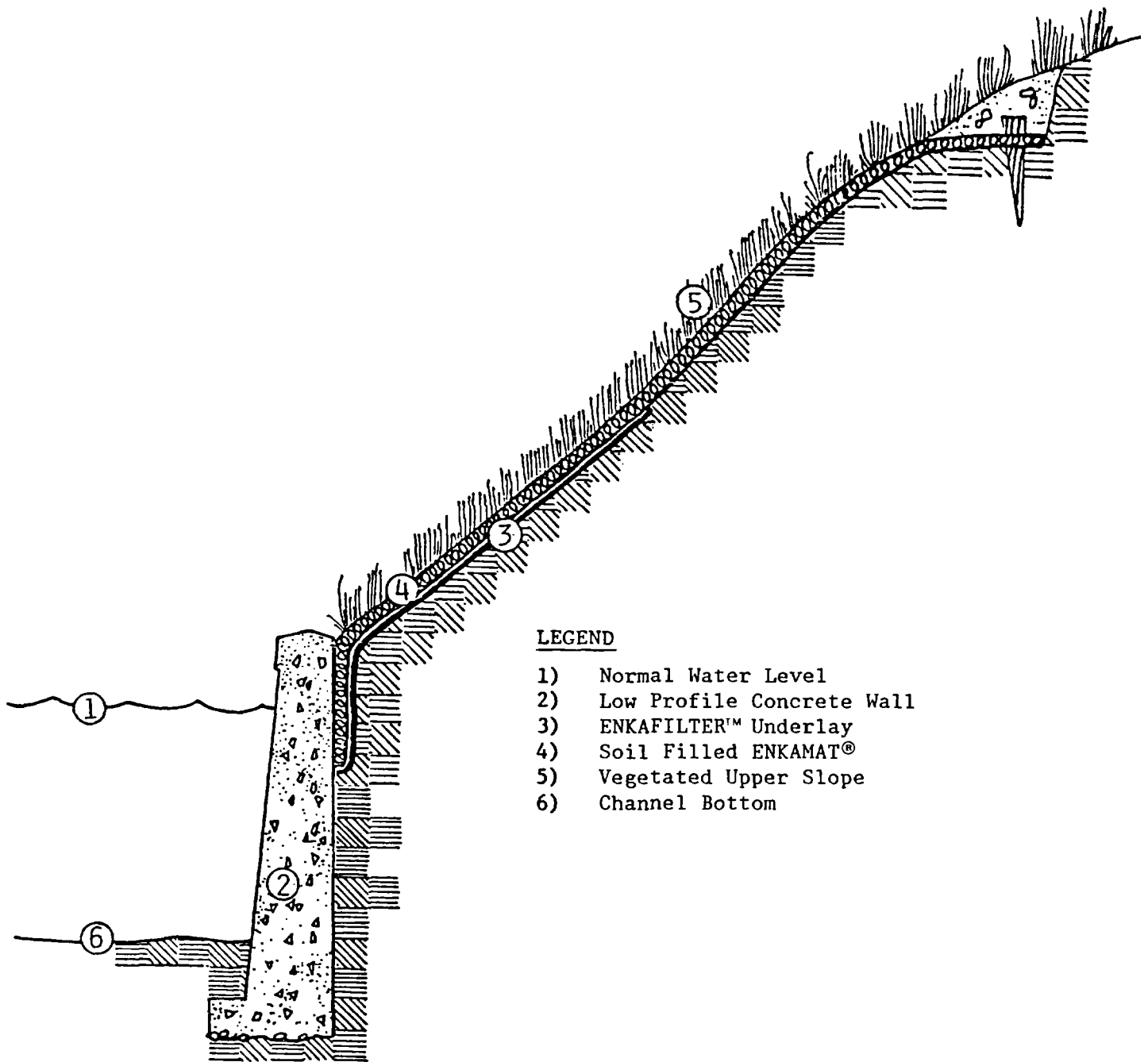


FIGURE 20 - SHORELINE PROTECTION - STEEP WATERWAY BANKS

(LOW-PROFILE WOODEN CHANNEL WALL)

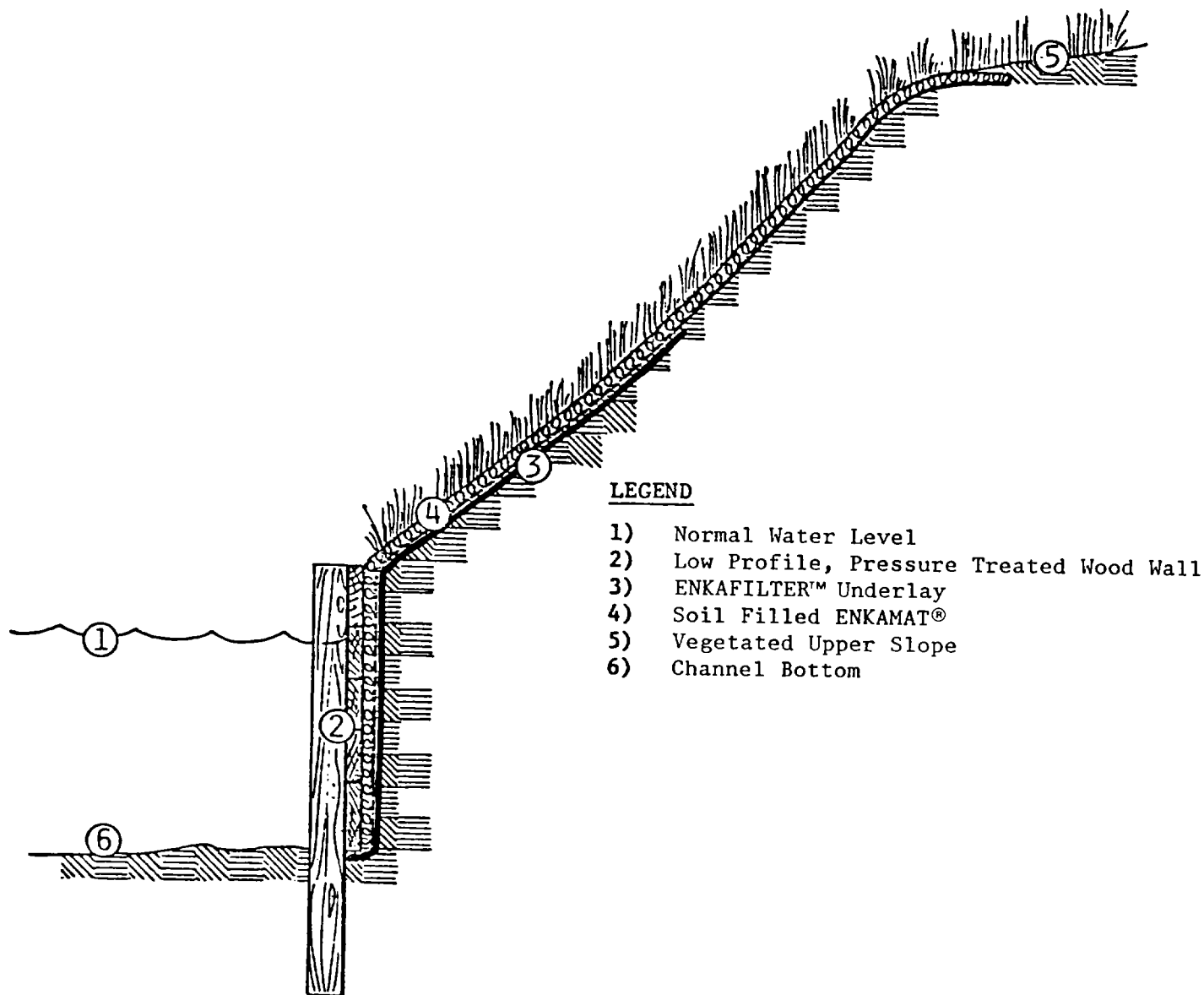
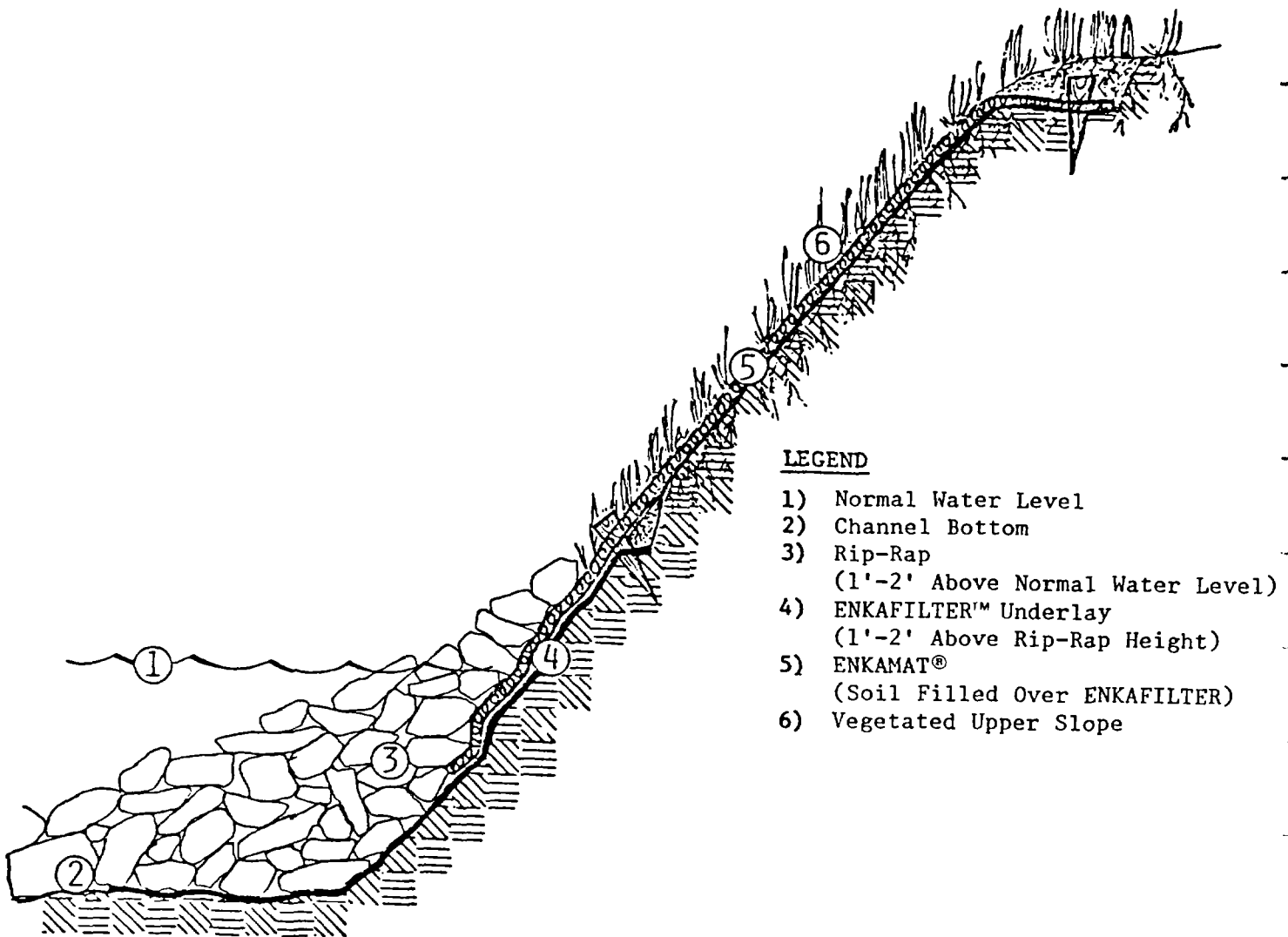


FIGURE 21 - SHORELINE PROTECTION - STEEP BANK SLOPES

(ROCK RIPRAP TOE)



2. Pond, Basin, Lake Shorelines

If banks extending out of water have steep slopes, it is suggested that a footing wall similar to those discussed be installed and the upper slope lined with ENKAMAT® using ENKAFILTER™ underlays, as required, on the lower regions.

However, if the water lines are bordered by shallow slopes, an effective and cost-saving system can afford protection against lapping wave action as follows:

A false toe is furrowed along the waterway. Depending on fluctuation of water levels, it is suggested that the furrowed "shelf" lies about 1' below the low watermarks with the back edge shaped to blend into the slope terrain about 1' above the high watermark. ENKAMAT with an ENKAFILTER underlay is then installed, running from the bottom of the furrow cup up to about one meter above the high watermark.

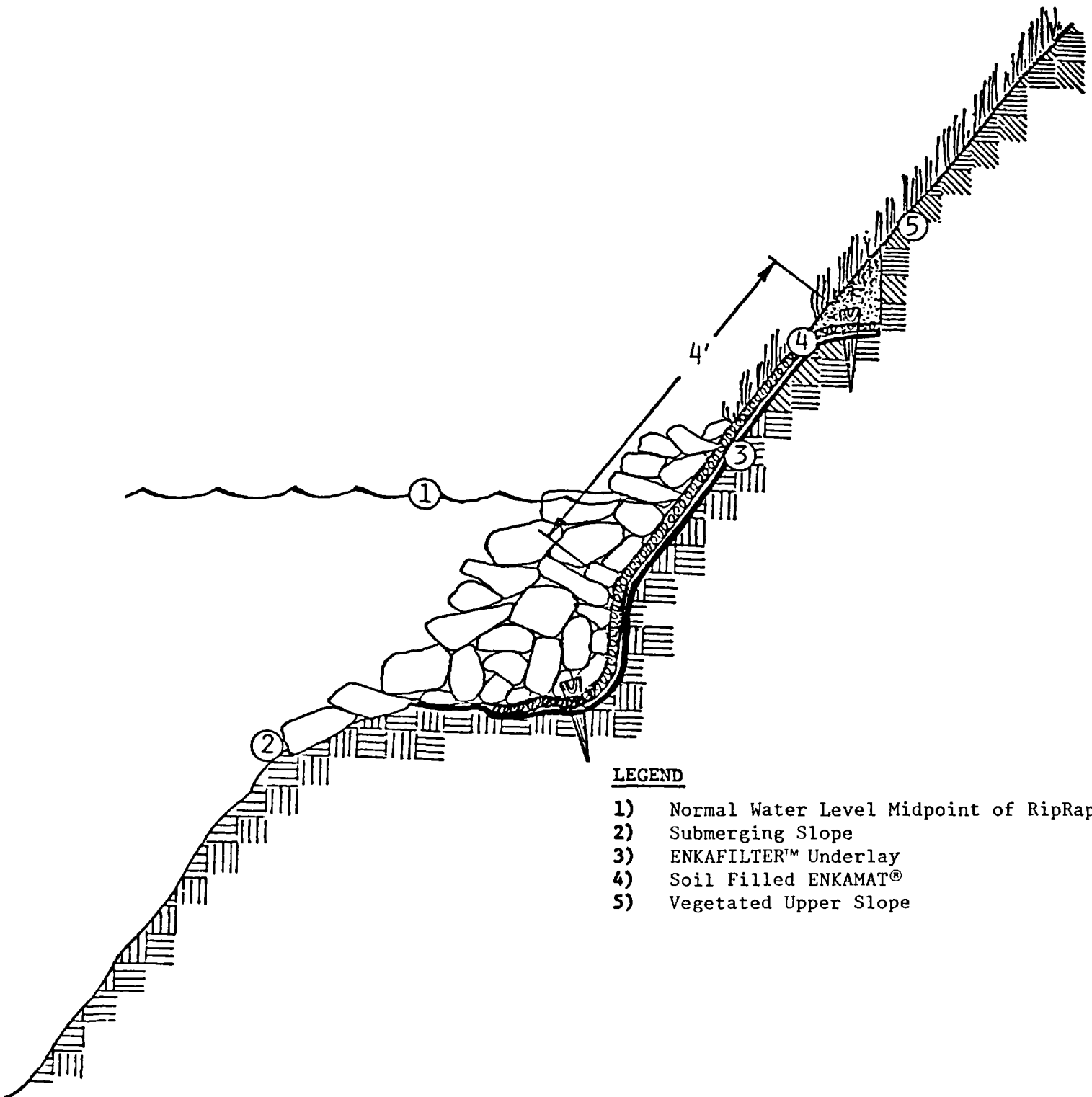
If shoreline soils are erosive (sand, silt), it is recommended that the false toe cup be covered with rock riprap (Figure 22).

If the soil is erosion resistant (heavy clays), the furrowed cup may be shallower and backfilled (Figure 23).

In each instance where the ENKAMAT is underlaid with ENKAFILTER, it must be covered with soil to produce a vegetative stand running upward from the water's edge.

FIGURE 22 - SHORELINE PROTECTION - SHALLOW BANK SLOPES

(ROCK RIPRAP IN FALSE TOE)

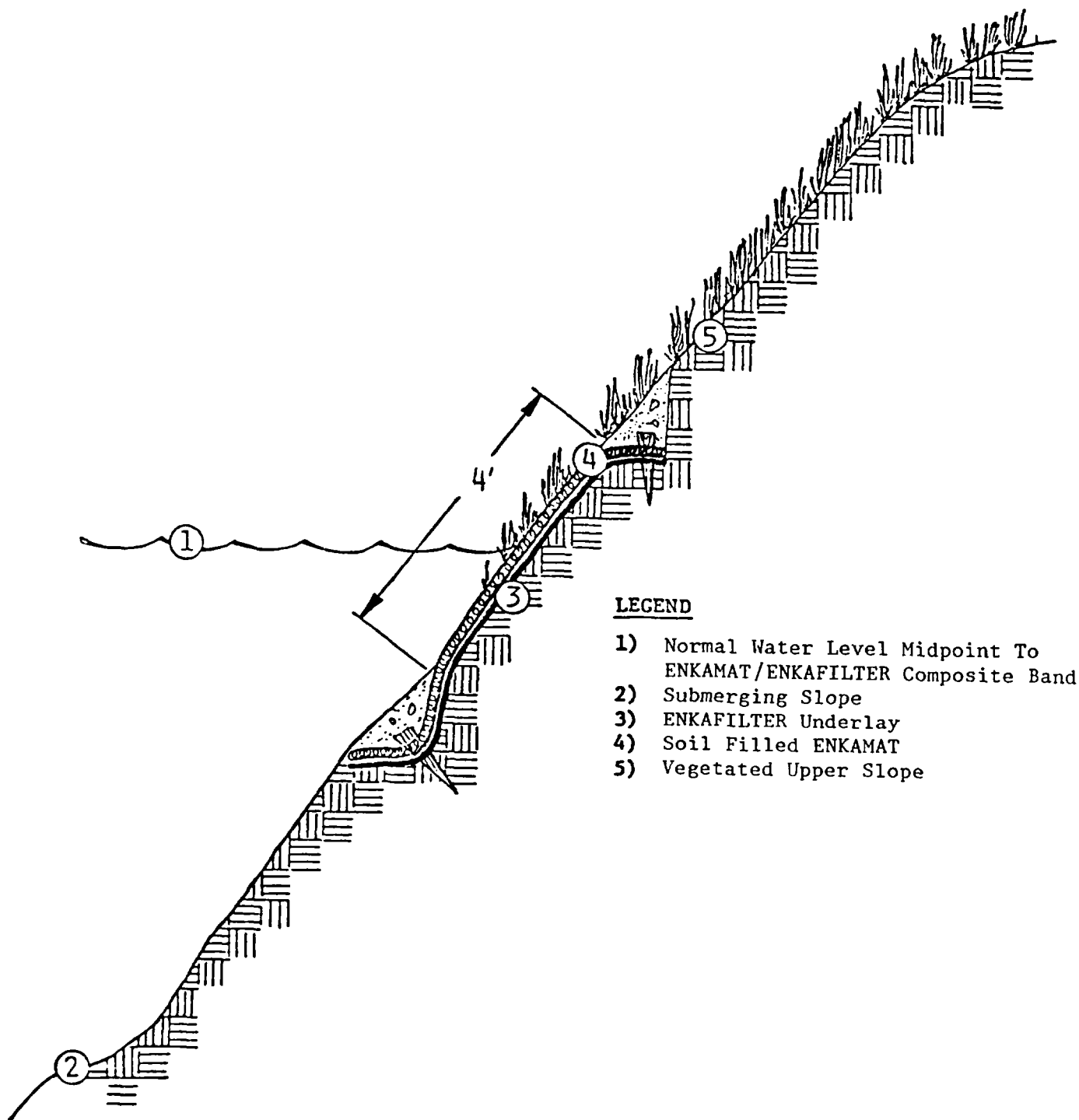


LEGEND

- 1) Normal Water Level Midpoint of RipRap
- 2) Submerging Slope
- 3) ENKAFILTER™ Underlay
- 4) Soil Filled ENKAMAT®
- 5) Vegetated Upper Slope

FIGURE 23 - SHORELINE PROTECTION - SHALLOW BANK SLOPES

(ENKAMAT®/ENKAFILTER™ BURIED INTO FALSE TOE)



SECTION III

INSTALLATION INSTRUCTIONS

A. Preparation

1. Site Preparation - Whether slope or channel, site must be shaped to design specifications and then dressed to be free of soil clods, clumps, rocks, or vehicle imprints of any significant size that would prevent the ENKAMAT® from lying flush to surface contours. (Figures 24 and 24-A)

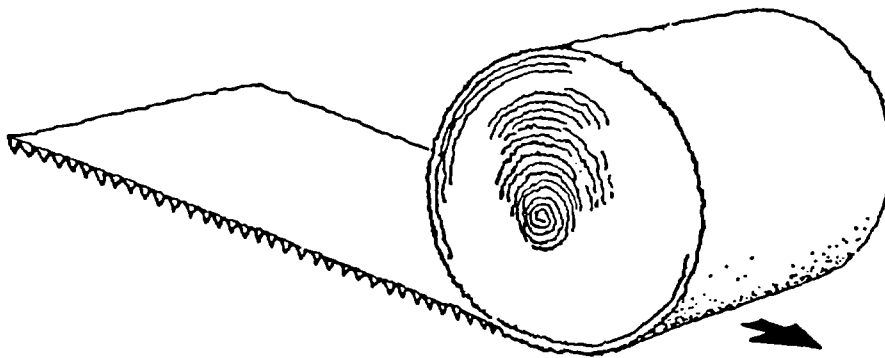
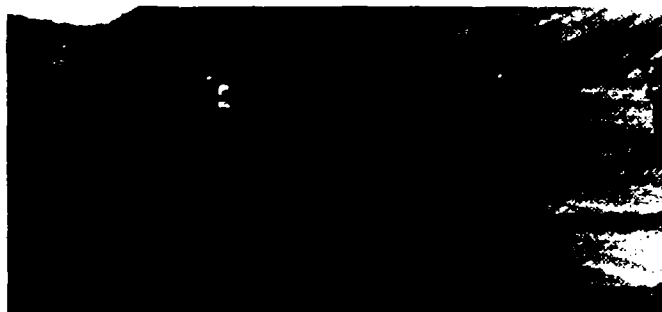


FIGURE 24 - ROLLING OUT THE ENKAMAT - PEAKS DOWN

A. Lining a Typical Roadside Channel

FIGURE A-1 - PICTORIAL VIEWS OF INSTALLATION APPROACH



a. Preparing Channel

Cutting check slots and side slope shelves after channel has been shaped and dressed.



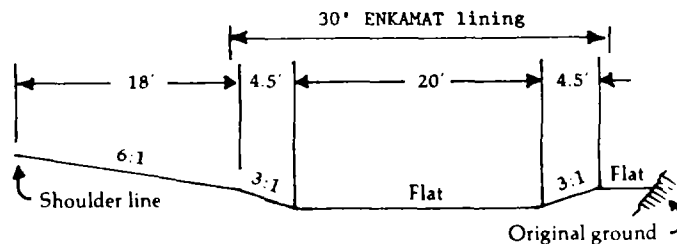
b. Start at Downstream End

Lower section of channel is laid as rolls progress upstream.



c. Progress Upstream

ENKAMAT® rolls overlap preceding section by 3' and continue upstream.



TYPICAL DITCH SECTION

Roadside channel (S.R. 22 at Bear Den, North Dakota) designed to carry about 300-350 CFS at 10 f/s with a 1' water depth.

B. Installation Procedure

1. General

Types, spacing, orientation, and positioning of stakes are critical. However, the following guidelines do not preclude good judgment.



FIGURE 24B - STAKE TYPE (TRIANGULAR)

FOR ENKAMAT®

Use triangular wooden stakes* that are cut to length from 1" x 3" standard slats. Cut diagonals across board flats to produce triangular configuration.

Length**

Soil Conditions

12"

Erosion-resistant soils - Cut channels and slopes in clays and gravels.

15"

Moderately erosion-resistant soils - Channels and compacted filled slopes containing silty and sandy clays.

Length**

Soil Conditions

18"

Erodible soils - Uncompacted channels and slopes containing fine silt, sand, or soft mud.

24"

Deep and soft fills, loose sands, silts, loams or "quick" conditions.

*Pressure-treated wood should be used where longevity is required.

**Project engineer should use his best judgment in selecting stake length for good binding, particularly where solid anchoring is essential.

FOR ENKAFILTER™

Use 9" x 1" No. 8 wire staples in order to hold ENKAFILTER underlay in place before laying ENKAMAT®.

2. Channel Installations

Supplemental notes to instructions.

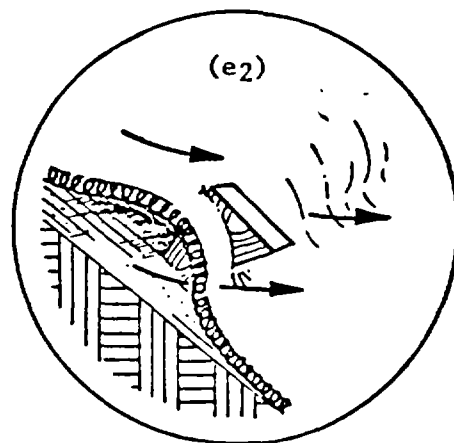
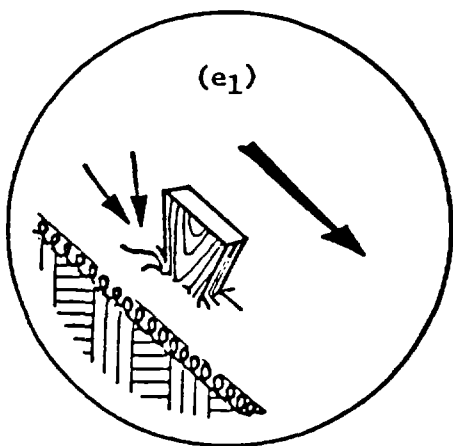
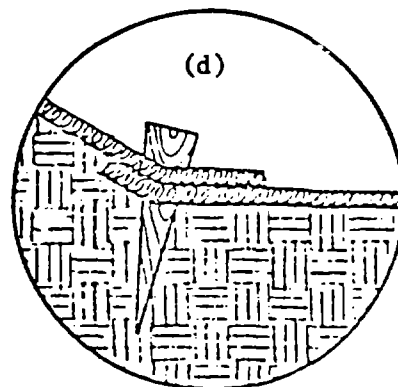
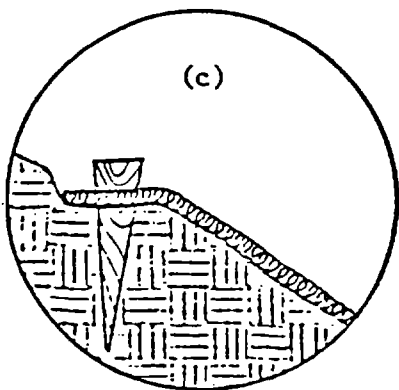
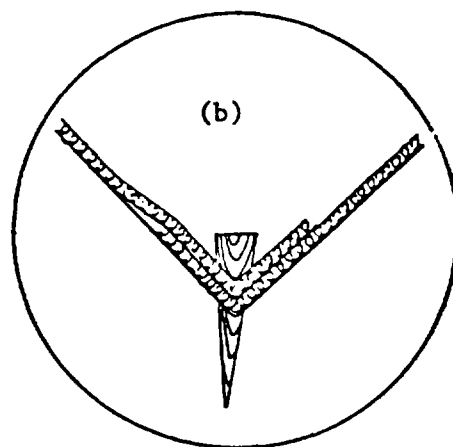
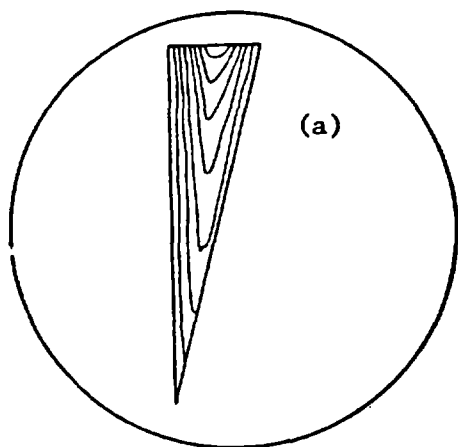
STAKE POSITIONS AND ORIENTATION

Figure 25

Notes

- | | Notes |
|-----|--|
| (a) | <ol style="list-style-type: none">1. Normally, orient stake to be broadside to stream flow.2. Wire staples are <u>not</u> recommended for fastening ENKAMAT®. They may be conveniently used to hold ENKAFILTER™ in place prior to laying ENKAMAT in composite structures. |
| (b) | Overlap and stake ENKAMAT into bottom apex of triangular-shaped channel. |
| (c) | Stake upper edge of ENKAMAT onto 4" wide ledge before burying. Diagonal edge of stake is faced inboard. |
| (d) | In a trapezoidal channel, overlap and stake ENKAMAT into the slope upturn of toe. Overlap is to be shingled downslope. |
| (e) | Overlap of channel linings having edges exposed to stream flow from converging channels should be staked broadside to its stream. STAKE--diagonal edge should face upstream (e ₁). If diagonal faces downstream, lift and shear forces tend to pull mat up and over stake (e ₂). |

FIGURE 25 - CRITICAL STAKE POSITION AND ORIENTATION



a. Standard Construction (Figures 26-28C)

(For channels laid on moderate to erosion-resistant soils designed to contain velocities up to about 10'-12' fps at a 1' depth.)

Using procedures outlined in the following illustrations, start installation at the downstream terminal and proceed upstream.

b. Reinforced Construction (Figures 29-31A)

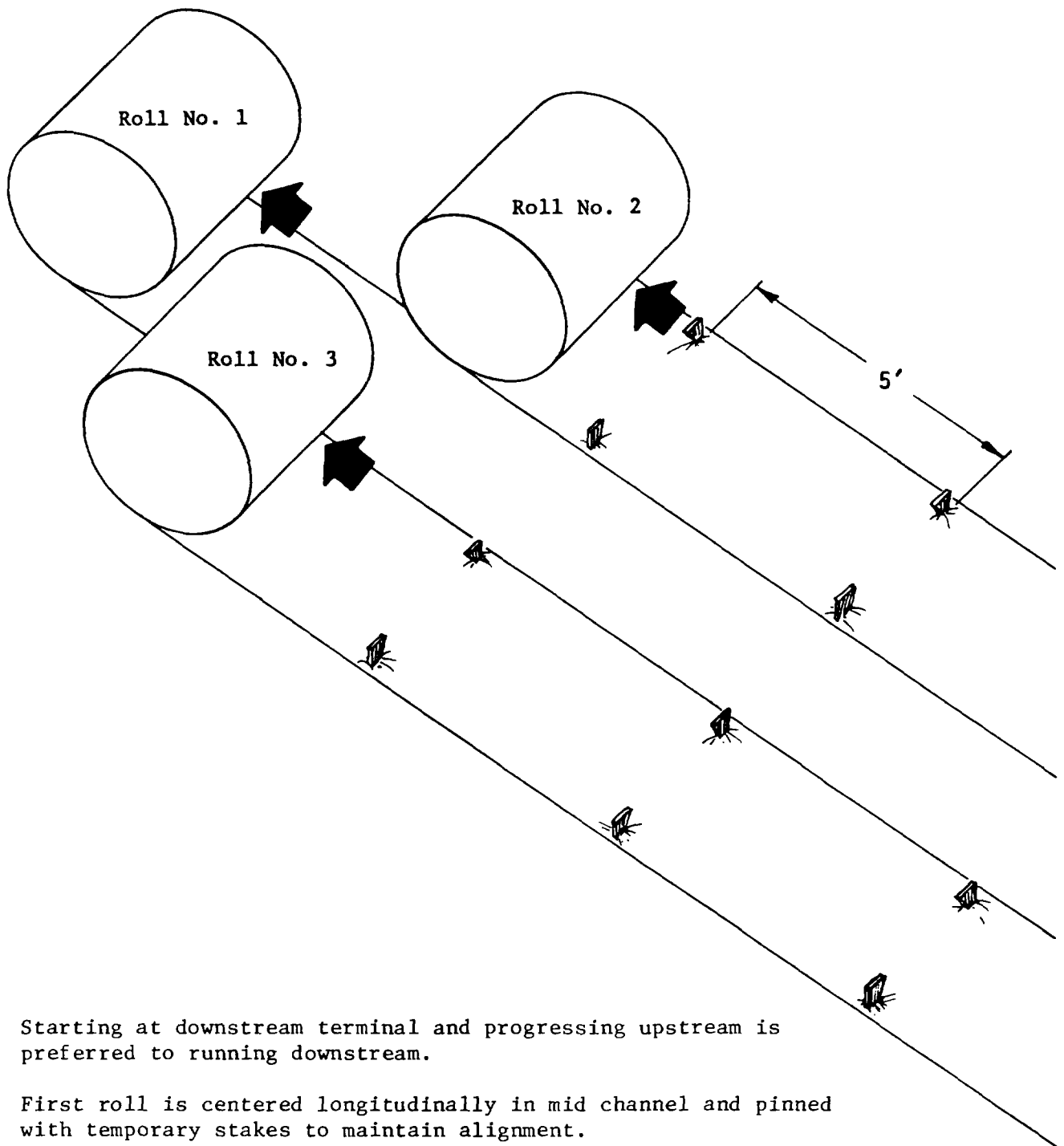
(For channels laid on erosive soils and/or designed to contain in excess of about 10'-12' fps.)

Use procedures outlined in the following illustrations:

- (1) Step 1. Begin by installing upstream terminal. However, do not proceed downstream at this stage. Leave lower ends of ENKAMAT® free until ready to overlay properly.
- (2) Step 2. Install downstream terminal and progress upstream.
- (3) Step 3. Progress upstream across transverse check slot, as shown.
- (4) Step 4. Take loose ends extending from previously installed upstream terminal and overlay on cutoff in Step 3.

FIGURE 26 - INSTALLING ENKAMAT® - STANDARD CONSTRUCTION

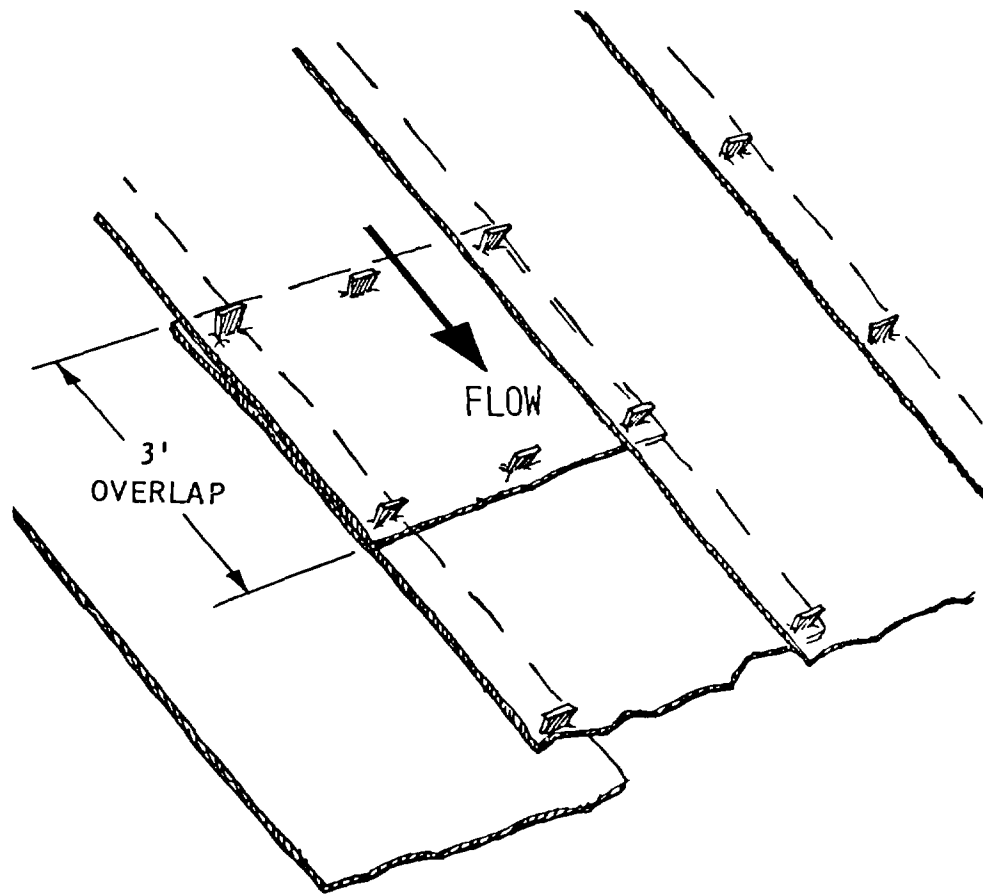
SEQUENTIAL ROLL RUN OUT IN CHANNELS



1. Starting at downstream terminal and progressing upstream is preferred to running downstream.
2. First roll is centered longitudinally in mid channel and pinned with temporary stakes to maintain alignment.
3. Subsequent rolls follow in staggered sequence behind first roll. Use center roll for alignment to channel center.
4. Work outwards from channel center to edge.
5. Use 4" overlap and stake at 5' intervals along seams.
6. Use 3' overlaps and shingle downstream to connect lining at roll ends (Figure 27).

FIGURE 27 - INSTALLING ENKAMAT® - STANDARD CONSTRUCTION

STAKING PATTERN AT ROLL TERMINALS



Roll Ends Shingled Downstream With 3-Foot Overlap

FIGURE 28 - ENKAMAT® CHANNEL LINING - TERMINAL AND TRANSVERSE CHECK SLOTS

STANDARD CONSTRUCTION

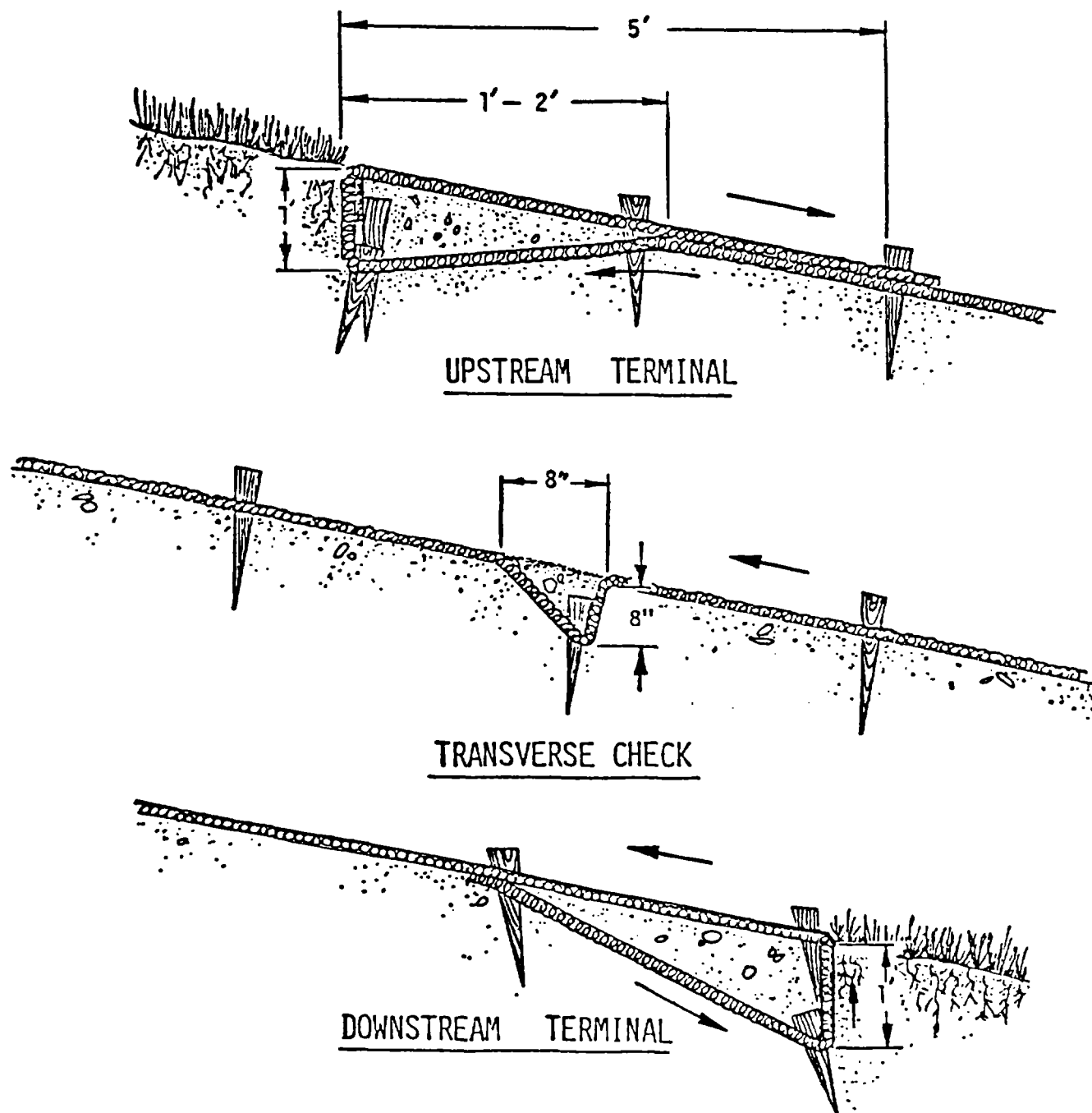
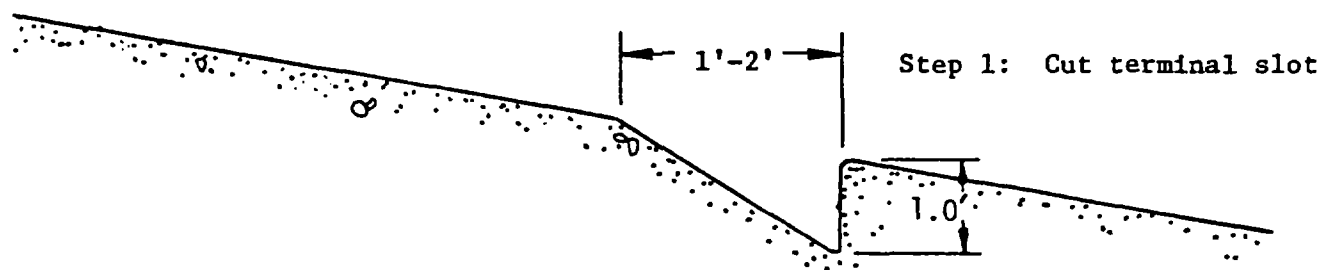
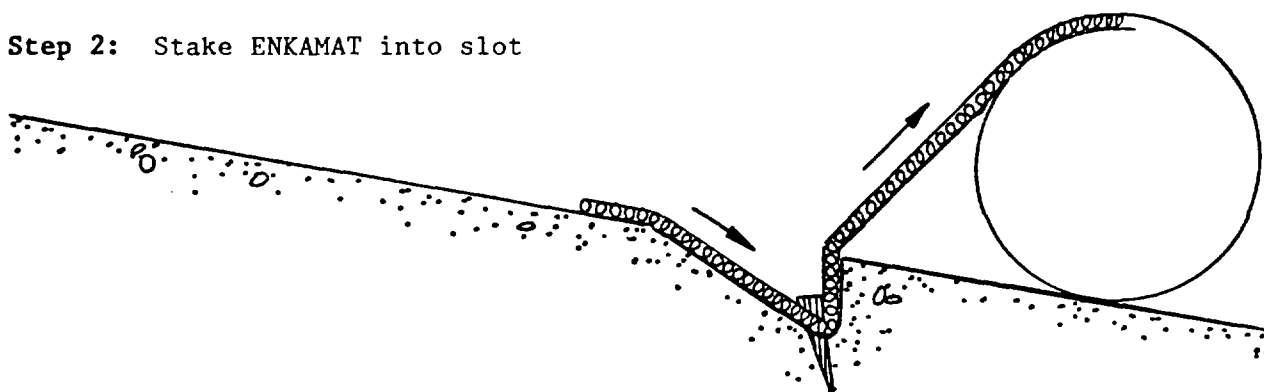


FIGURE 28A - INSTALLING ENKAMAT® - STANDARD CHANNEL CONSTRUCTION

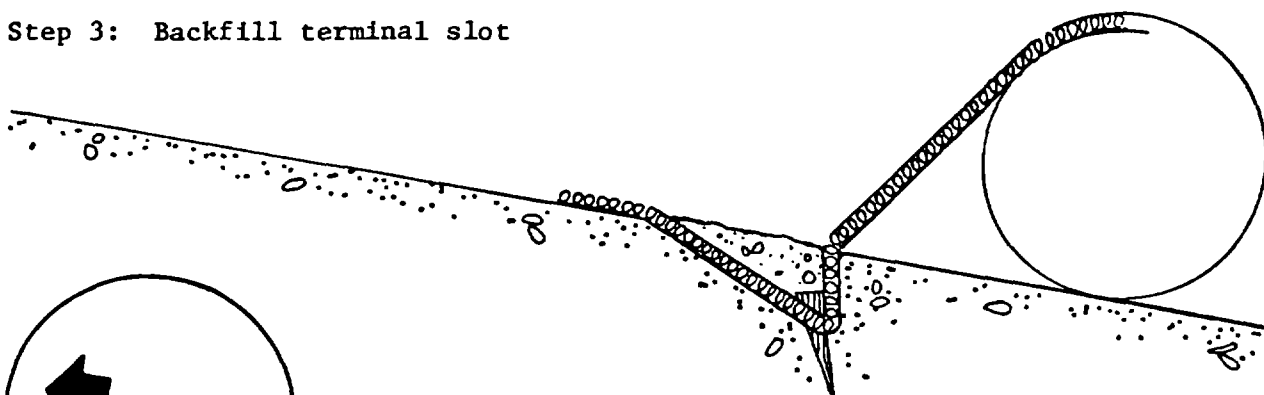
DOWNSTREAM TERMINAL



Step 2: Stake ENKAMAT into slot



Step 3: Backfill terminal slot



Step 4: (a) Roll mat upstream over refilled terminal
(b) Stake mat down to anchor terminal
(c) Progress upstream with ENKAMAT roll

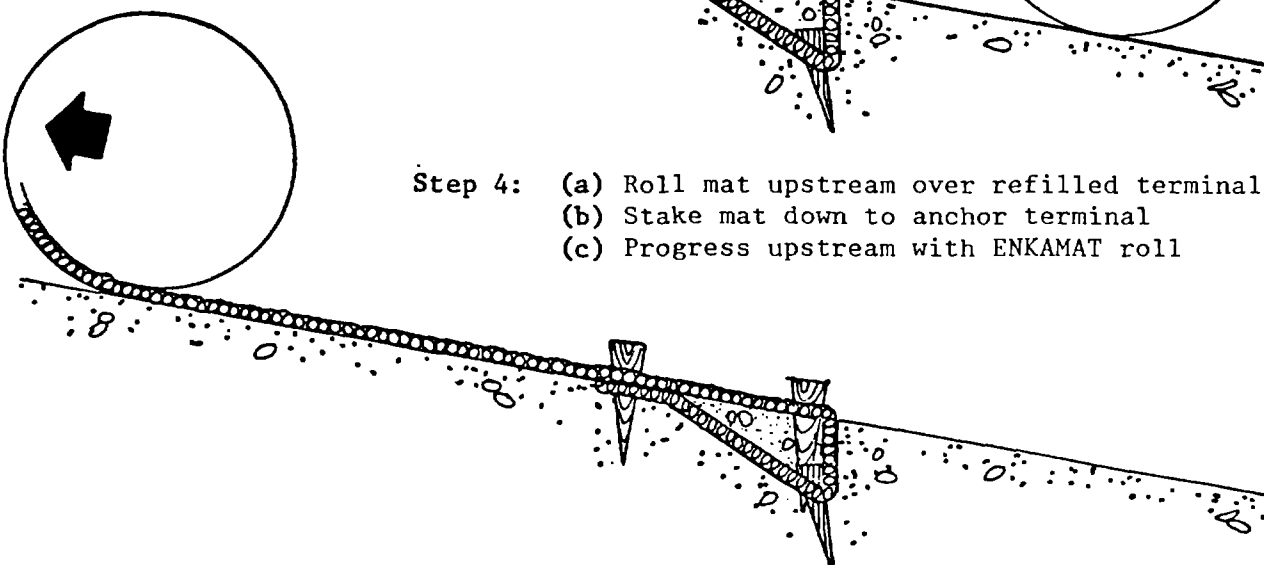


FIGURE 28B - INSTALLING ENKAMAT® - STANDARD CHANNEL CONSTRUCTION

TRANSVERSE CHECK SLOT

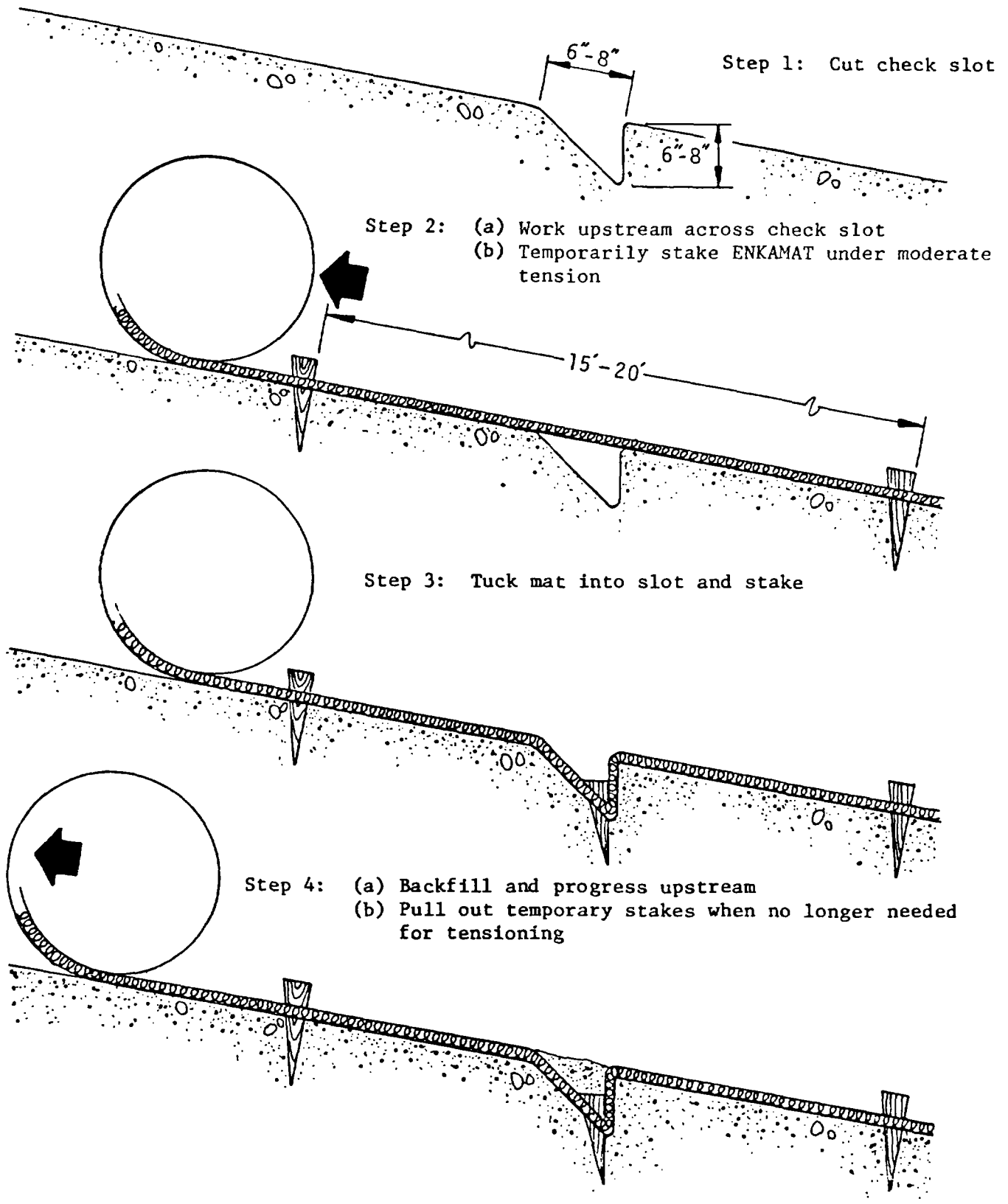
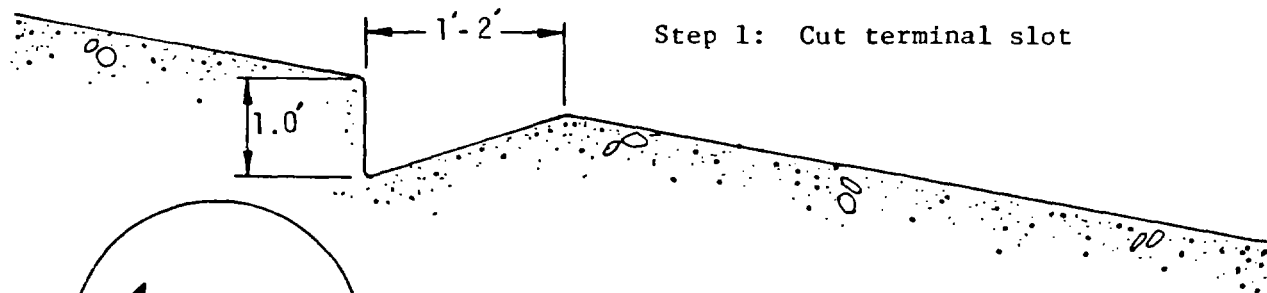
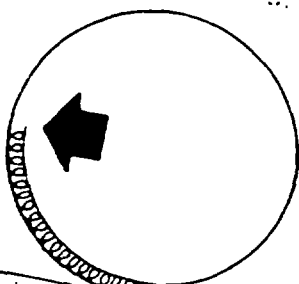


FIGURE 28C - INSTALLING ENKAMAT® - STANDARD CHANNEL CONSTRUCTION

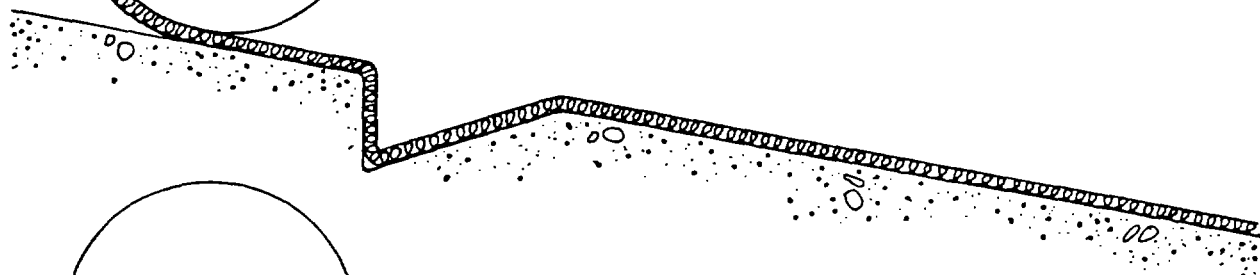
UPSTREAM TERMINAL



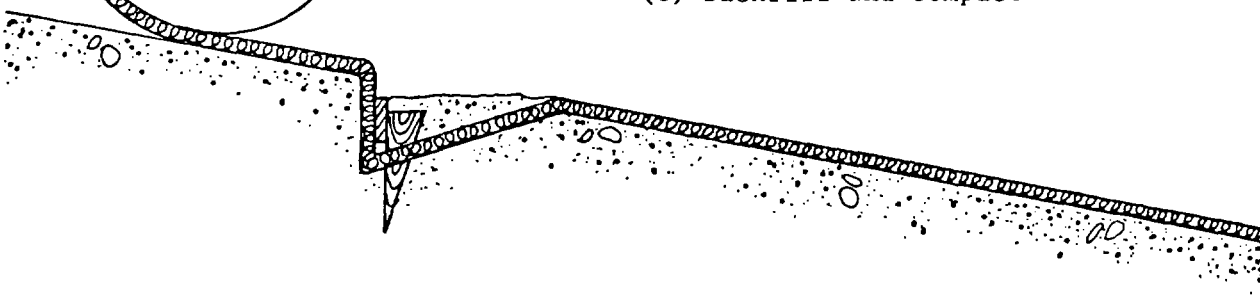
Step 1: Cut terminal slot



Step 2: Snug ENKAMAT into slot



Step 3: (a) Stake ENKAMAT into slot
(b) Use 1" x 3" pressure-treated board to brace ENKAMAT against vertical cut
(c) Backfill and compact



Step 4: (a) Reverse ENKAMAT roll direction to overlay check slot
(b) Stake ENKAMAT to anchor terminal

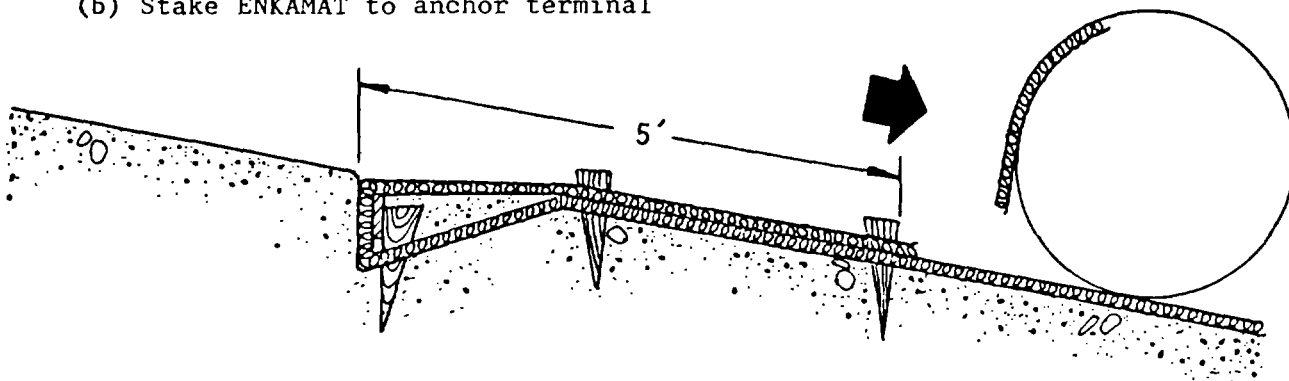


FIGURE 29 - ENKAMAT® CHANNEL LINING - UPSTREAM TERMINAL
REINFORCED CONSTRUCTION

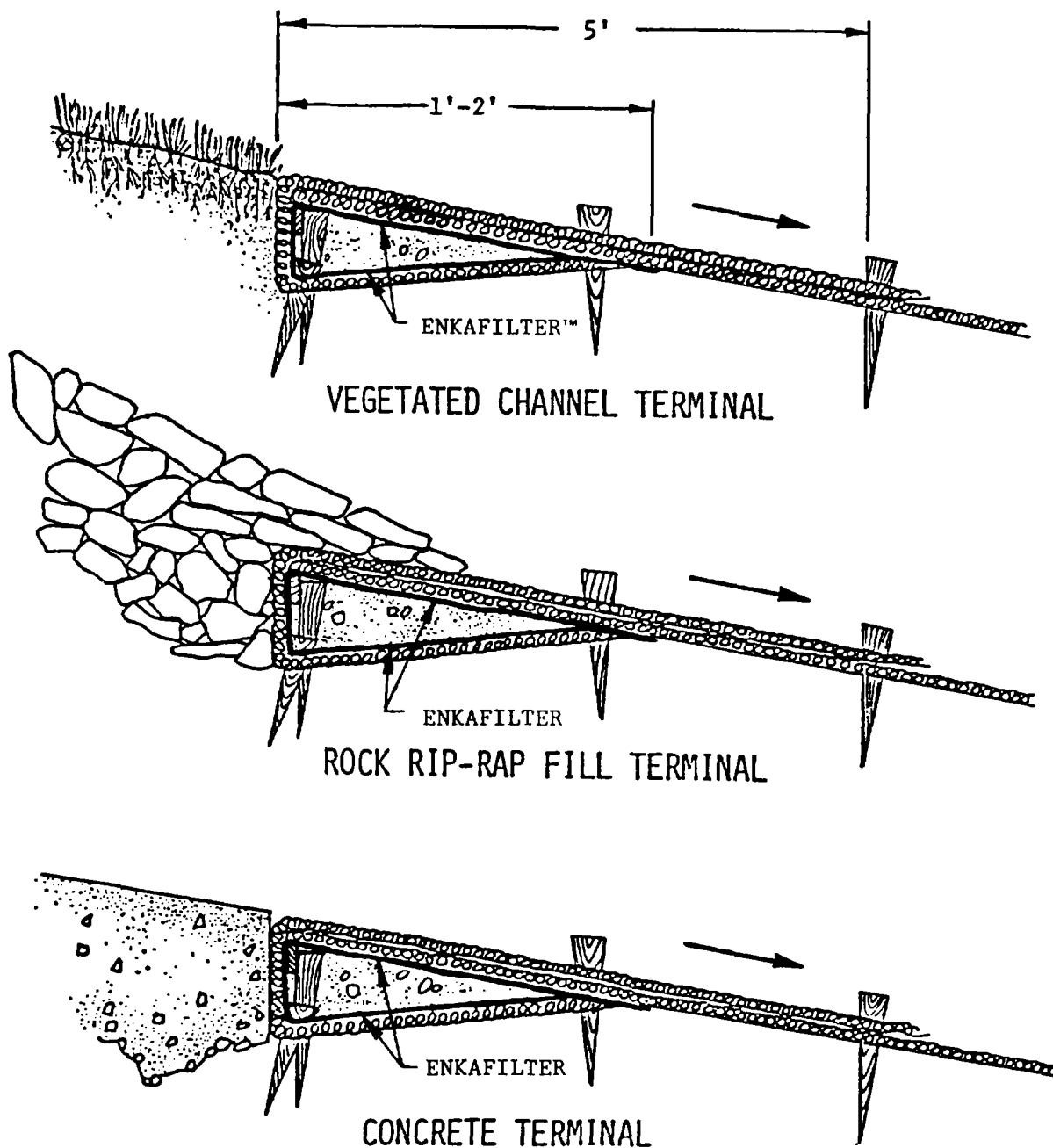


FIGURE 29A - INSTALLING ENKAMAT® - REINFORCED CONSTRUCTION

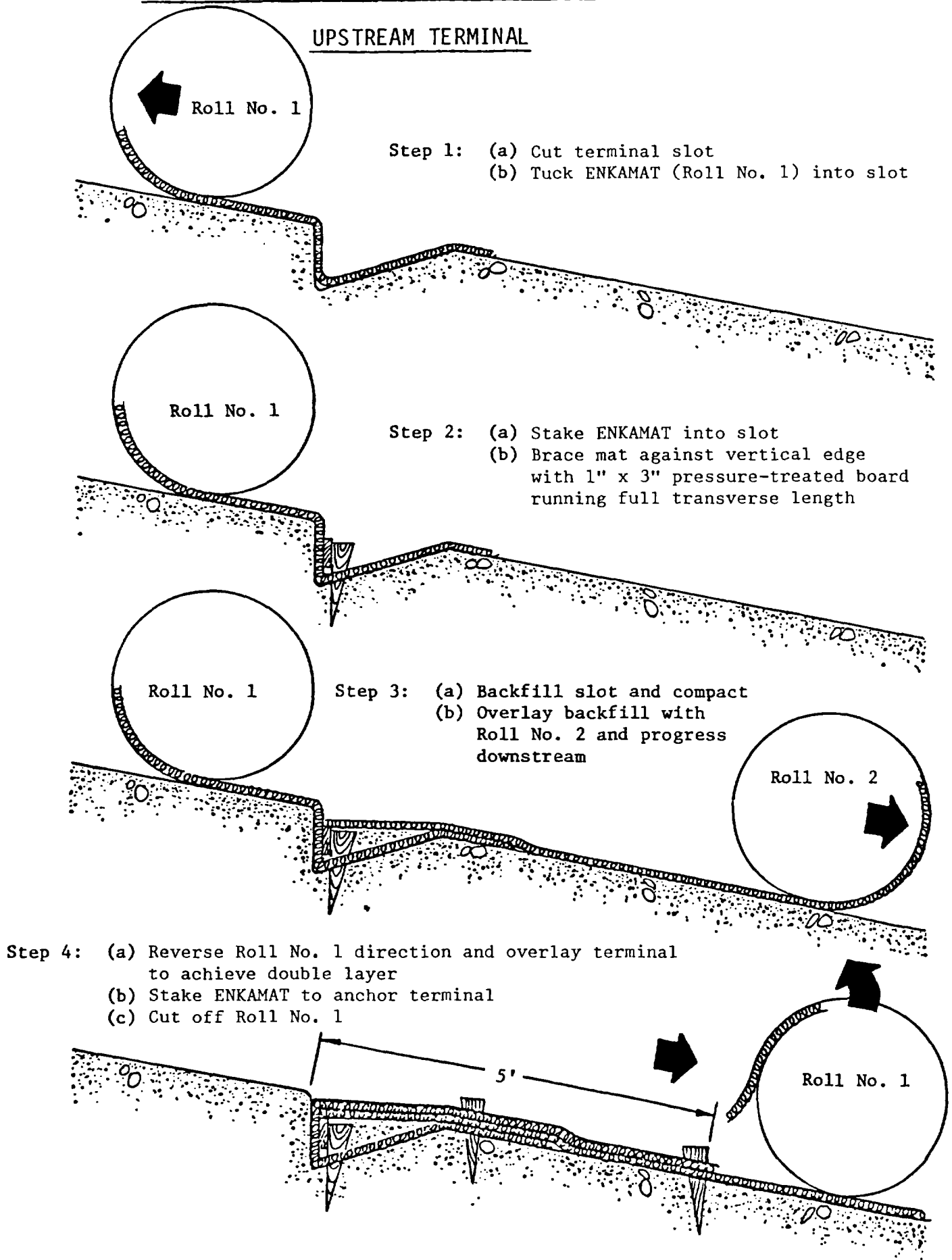


FIGURE 30 - ENKAMAT® CHANNEL LINING - DOWNSTREAM TERMINAL

REINFORCED CONSTRUCTION

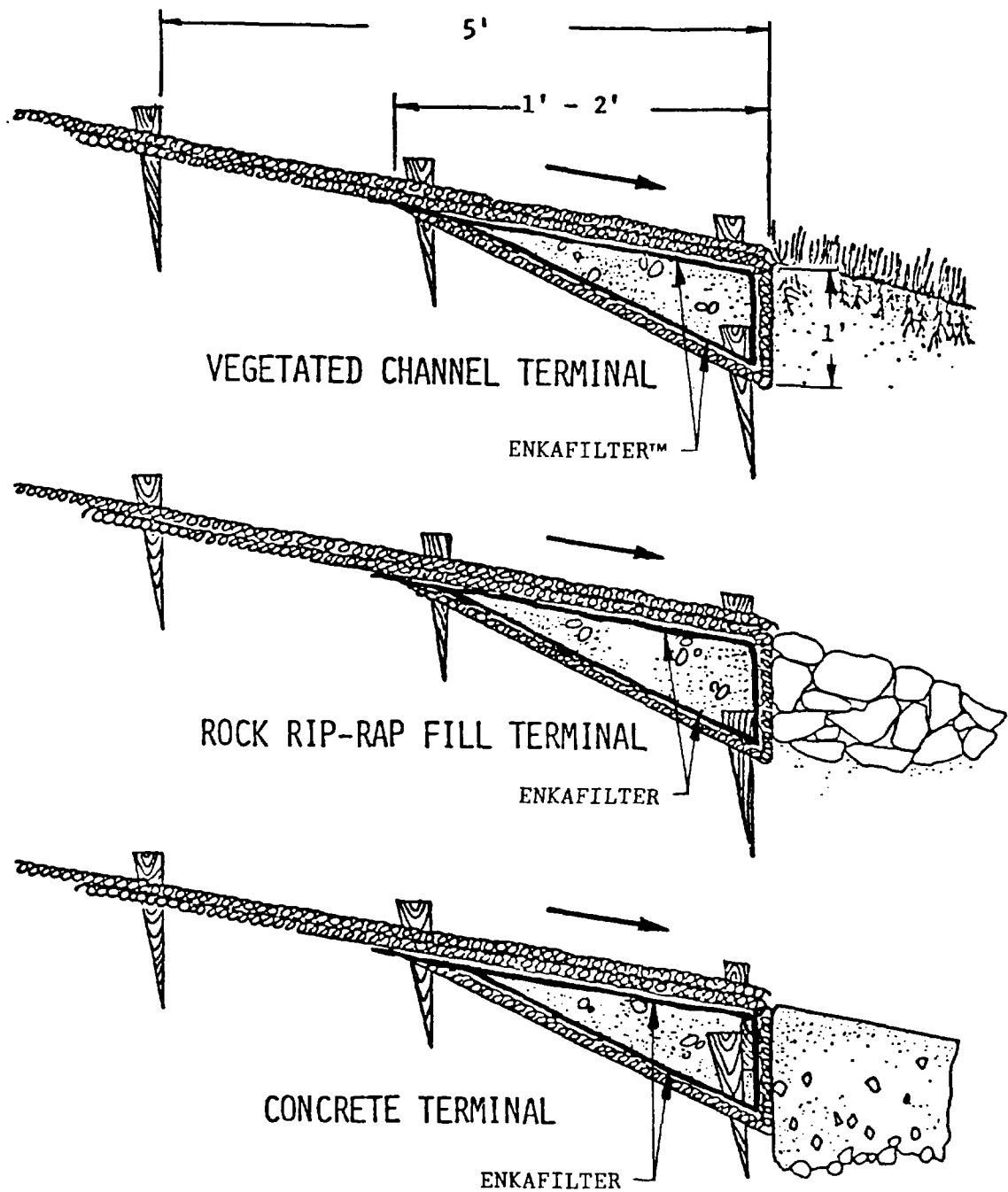


FIGURE 30A - INSTALLING ENKAMAT® - REINFORCED CONSTRUCTION

DOWNSTREAM TERMINAL

- Step 1: (a) Cut downstream terminal slot
(b) Tuck into and stake down ENKAMAT

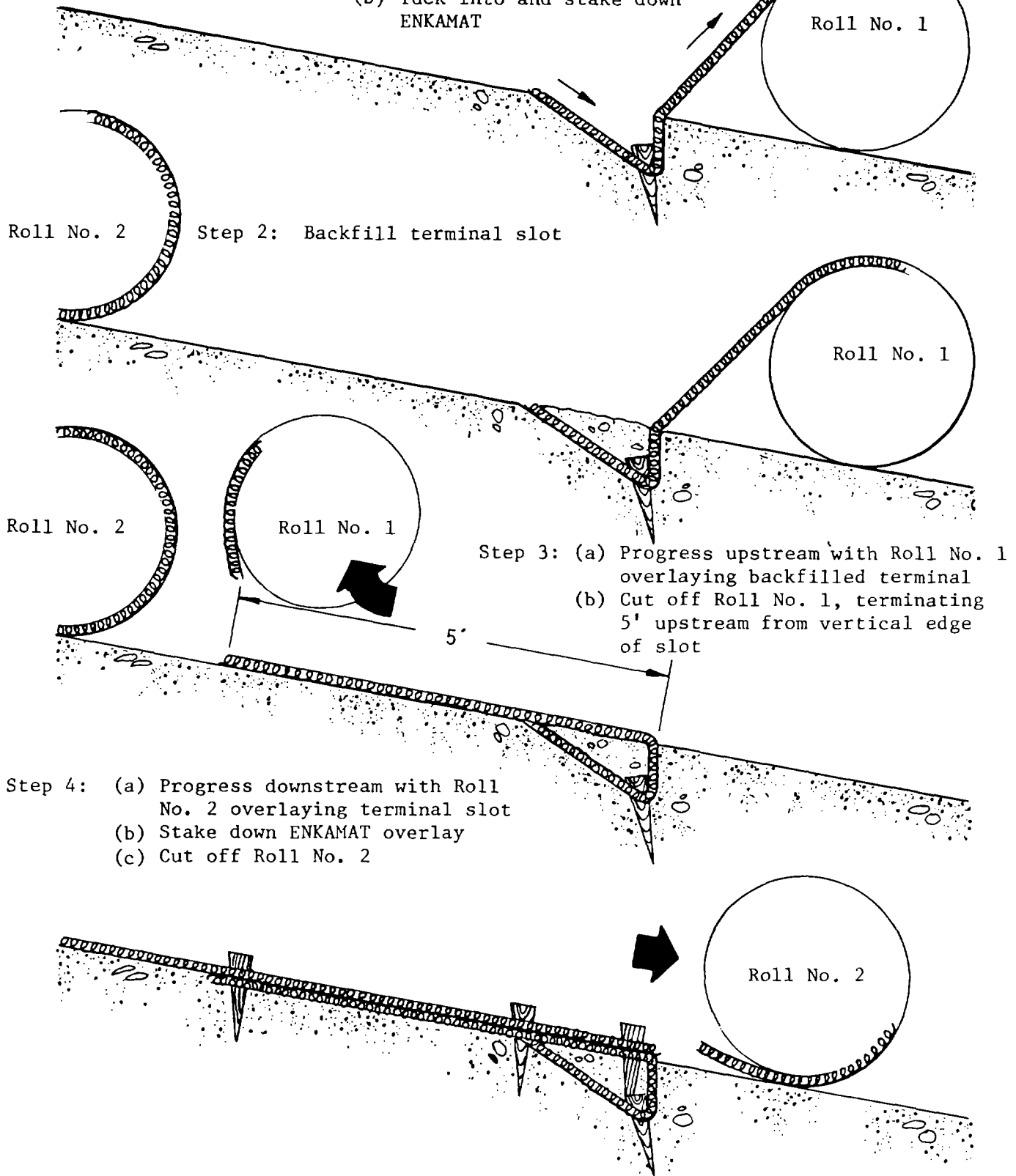


FIGURE 31 - ENKAMAT® CHANNEL LINING - TRANSVERSE CHECK SLOT

REINFORCED CONSTRUCTION

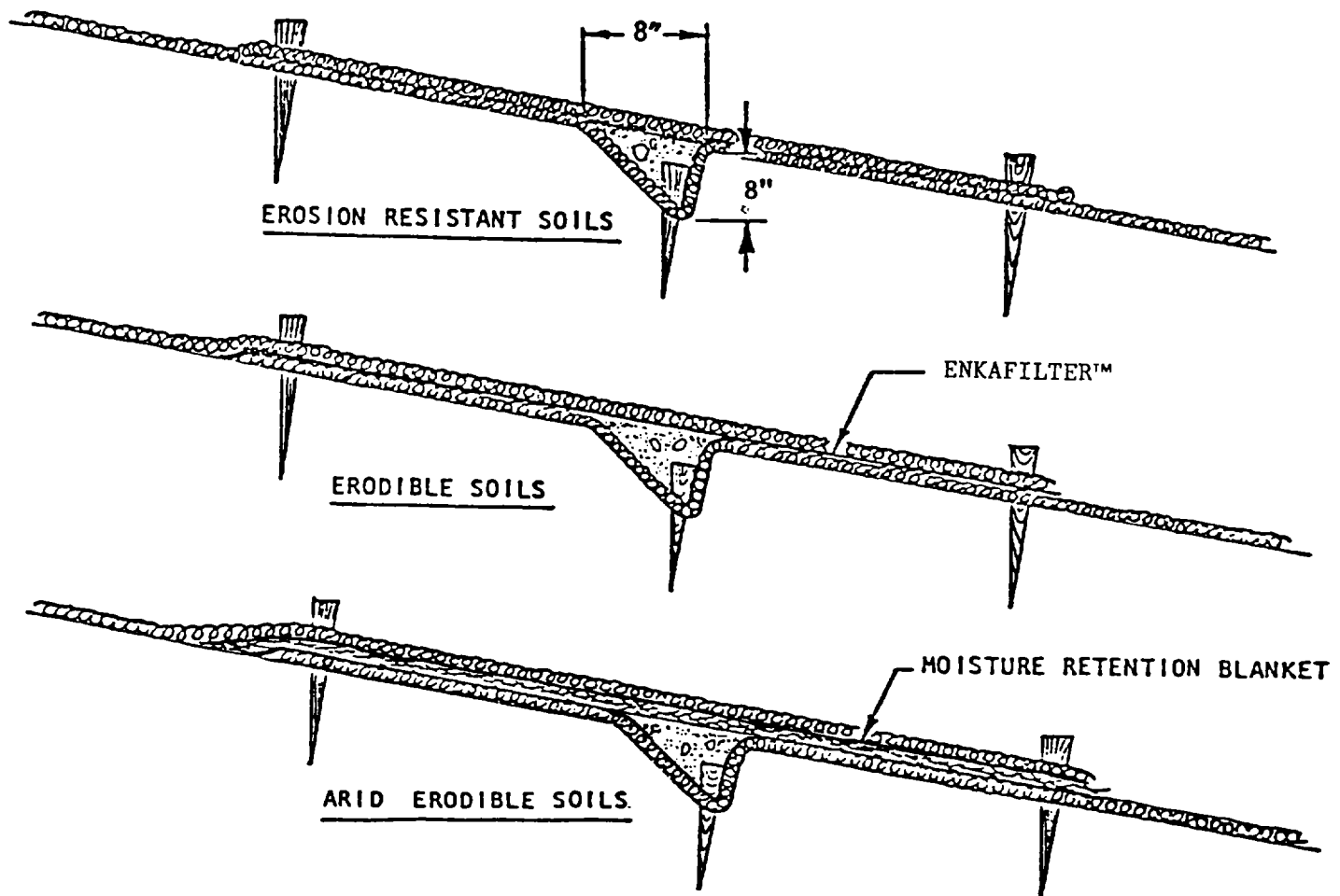
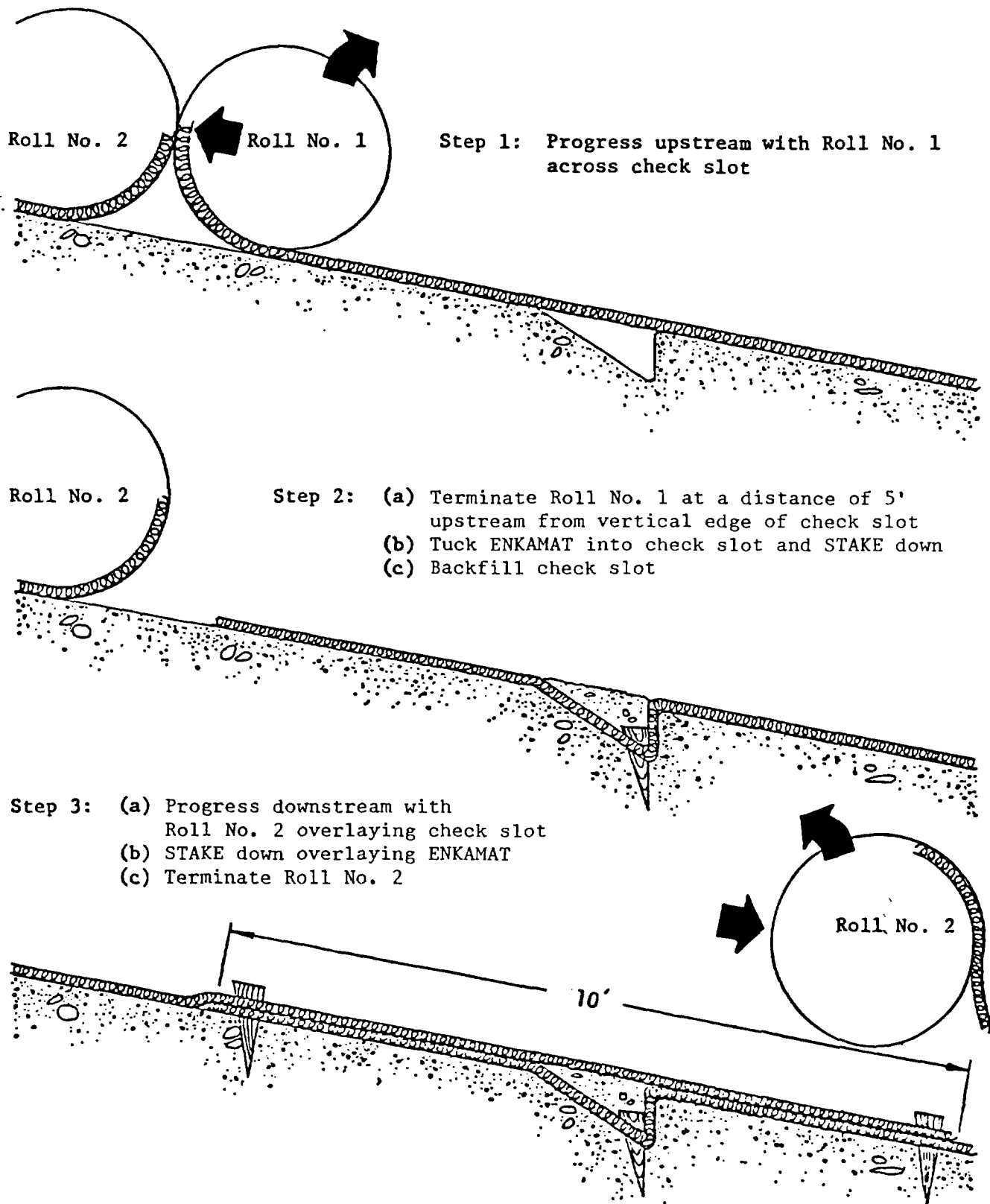


FIGURE 31A - INSTALLING ENKAMAT® - REINFORCED CONSTRUCTION

TRANSVERSE CHECK SLOT



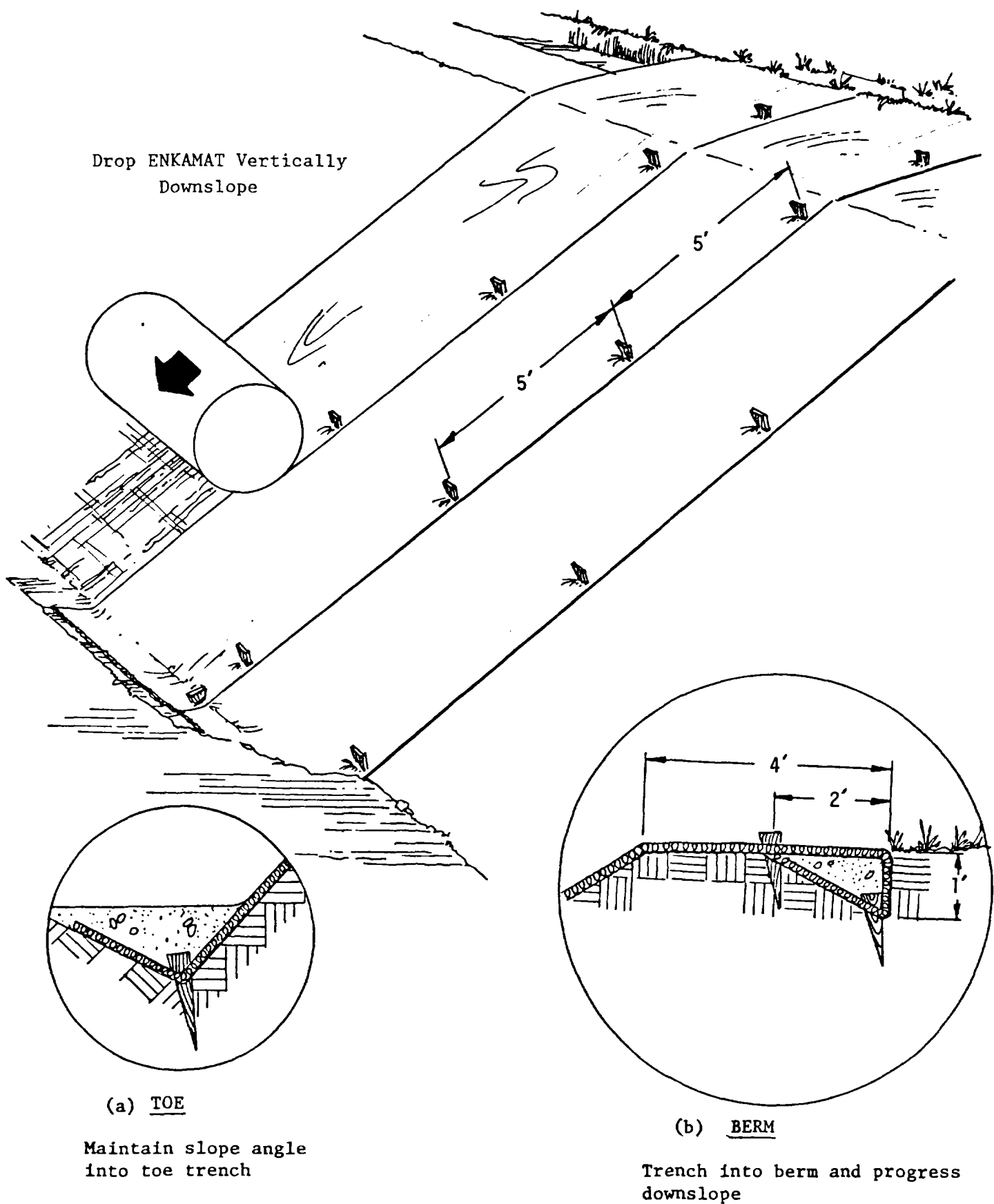
3. Slope Installation

a. General (Figure 32)

- (1) Run ENKAMAT® vertically downslope on all banks and slopes that are higher than 6'-7'.
- (2) Overlap 4" at seams and set stakes at standard 5' intervals. On soft, deep-fill slopes and on lower portions of slopes subjected to aquifer or post flood drainage, decrease intervals to 3'. Stakes should be oriented to be broadside to slope with straight edge of stake at 1" distance from ENKAMAT overlap edge along seam.
- (3) Bury berm and toe terminals of ENKAMAT (Insets 32a and 32b).
- (4) Be sure to maintain slope angle into burial trench of toe (Inset 32a).

FIGURE 32 - INSTALLING ENKAMAT® ON SLOPES AND BANKS

STANDARD CONSTRUCTION



b. Special Notes for Avoiding Problems

- (1) Be sure that slope angle is continued into toe trench to a minimum depth of 1' for erosion-resistant soils and greater (2' or more) for erosive conditions (silt, sand, etc.) to prevent scour undercutting.
- (2) Where banks are cut into aquifer or are subject to post flood drainage, underlay ENKAMAT® with an ENKAFILTER™ fabric on lower portion of slope (Figure 33).

(a) Procedure for slopes subjected to drainage:

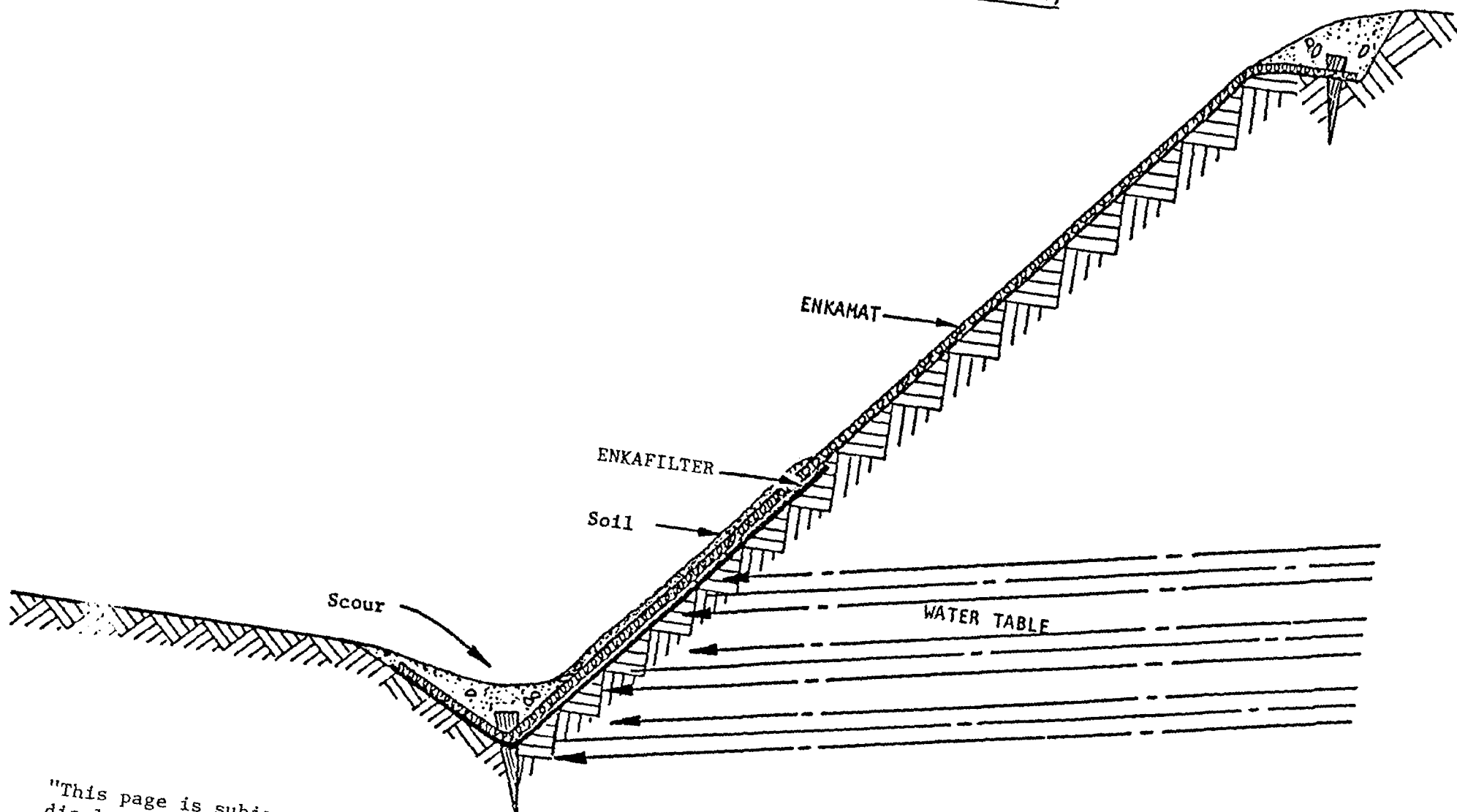
Step 1 - Dig berm and toe trenches (Figure 31 insets).

Step 2 - Run one width of 7' wide ENKAFILTER laterally along lower slope. Pin upper edge with wire staples at about 5' intervals. Tuck and stake lower edge into toe trench, using wire staples or temporary stakes (Figure 34).

Step 3 - Lay and stake ENKAMAT (Figure 33).

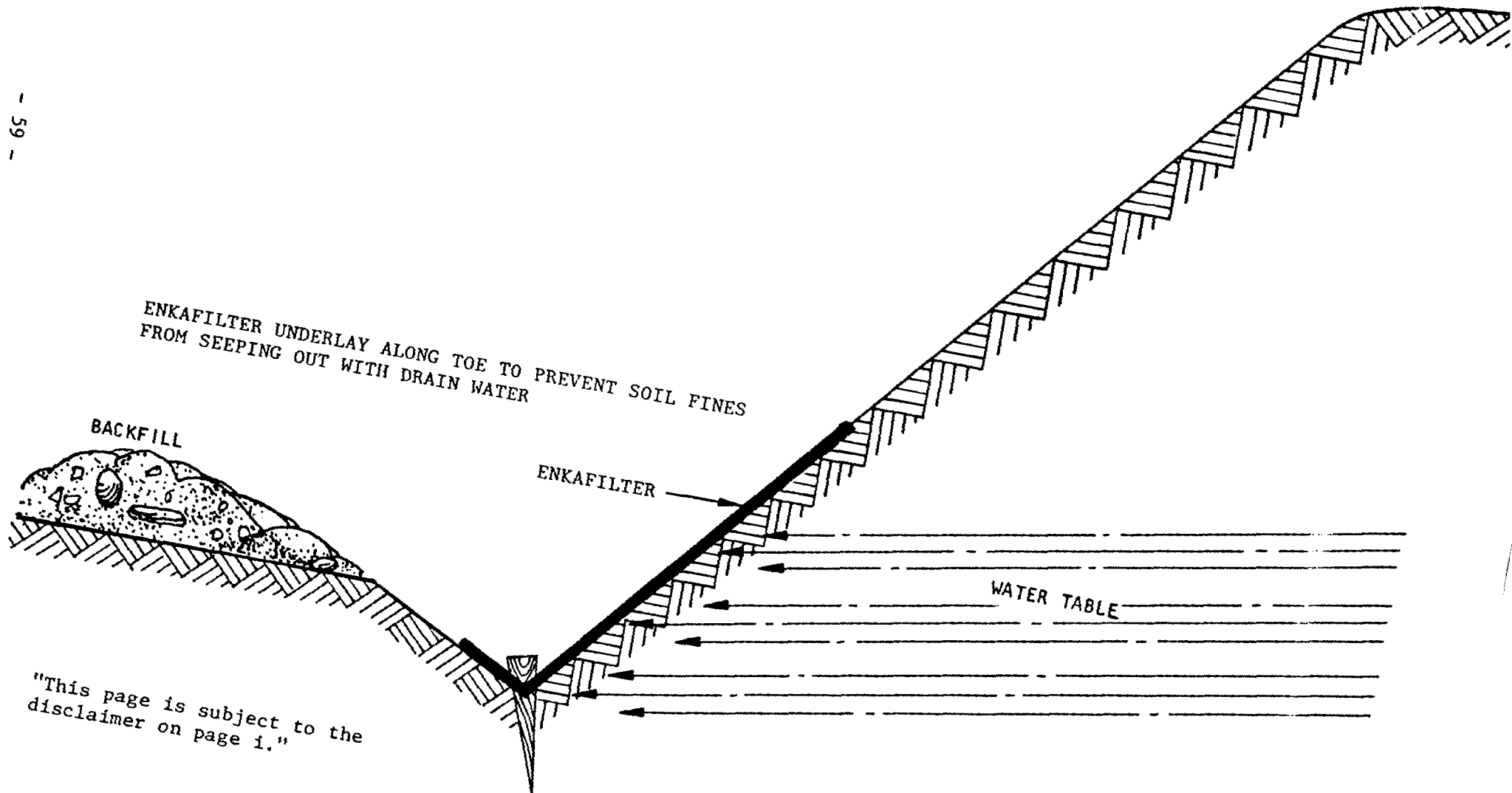
Step 4 - Backfill toe trench.

FIGURE 33 - ENKAMAT® LINING WITH ENKAFILTER™ UNDERLAY
(SLOPES AND BANKS SUBJECT TO DRAINAGE)



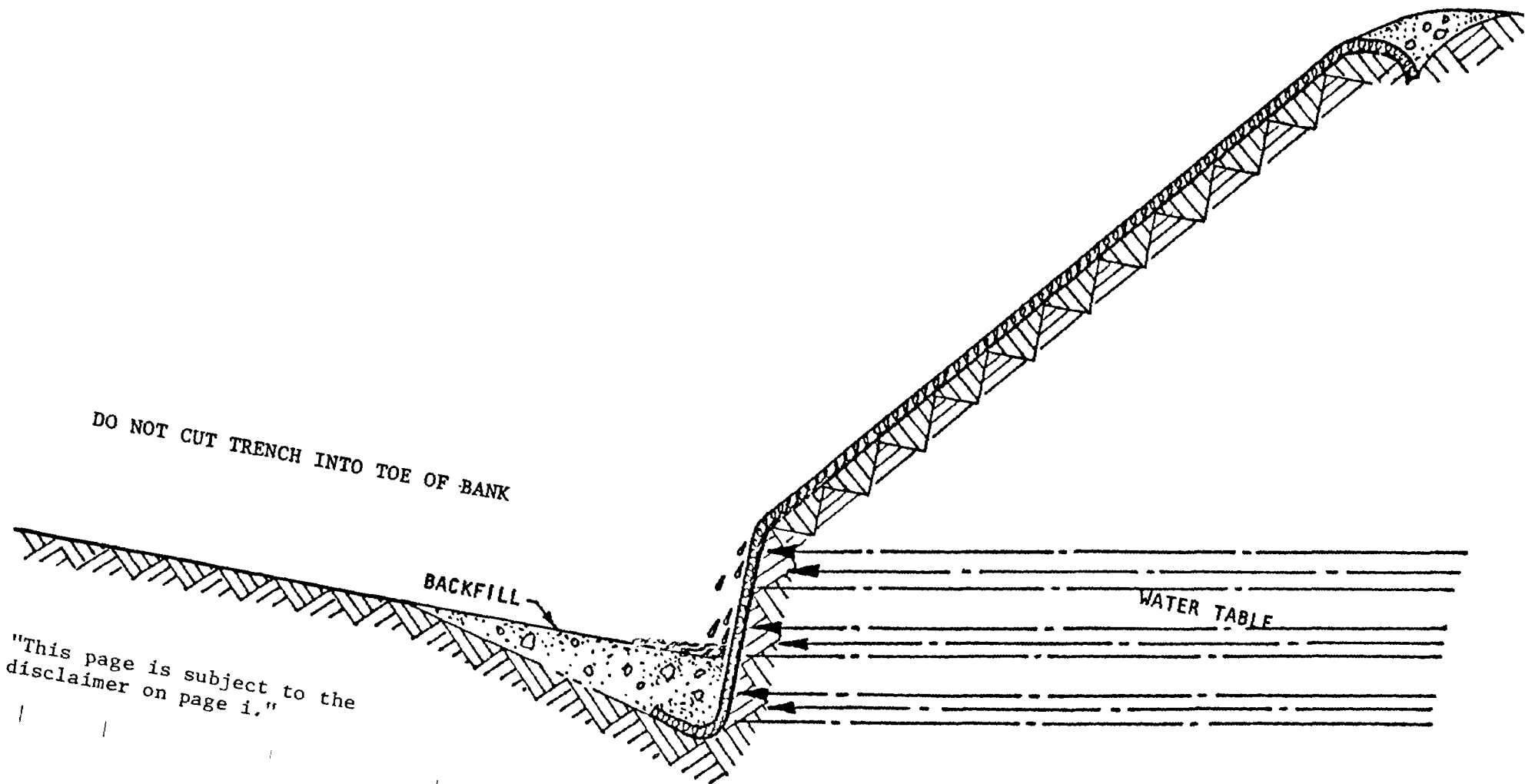
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FIGURE 33A - ENKAFILTER™ UNDERLAY FOR ENKAMAT® SLOPE



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disclaimer on page 1."

FIGURE 34 - INSTALLING ENKAMAT® ON BANKS - WRONG PROCEDURE



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FIGURE 35 - INSTALLING ENKAMAT® ON BANKS - WRONG PROCEDURE

DO NOT INSTALL ENKAMAT PARALLEL TO SLOPE

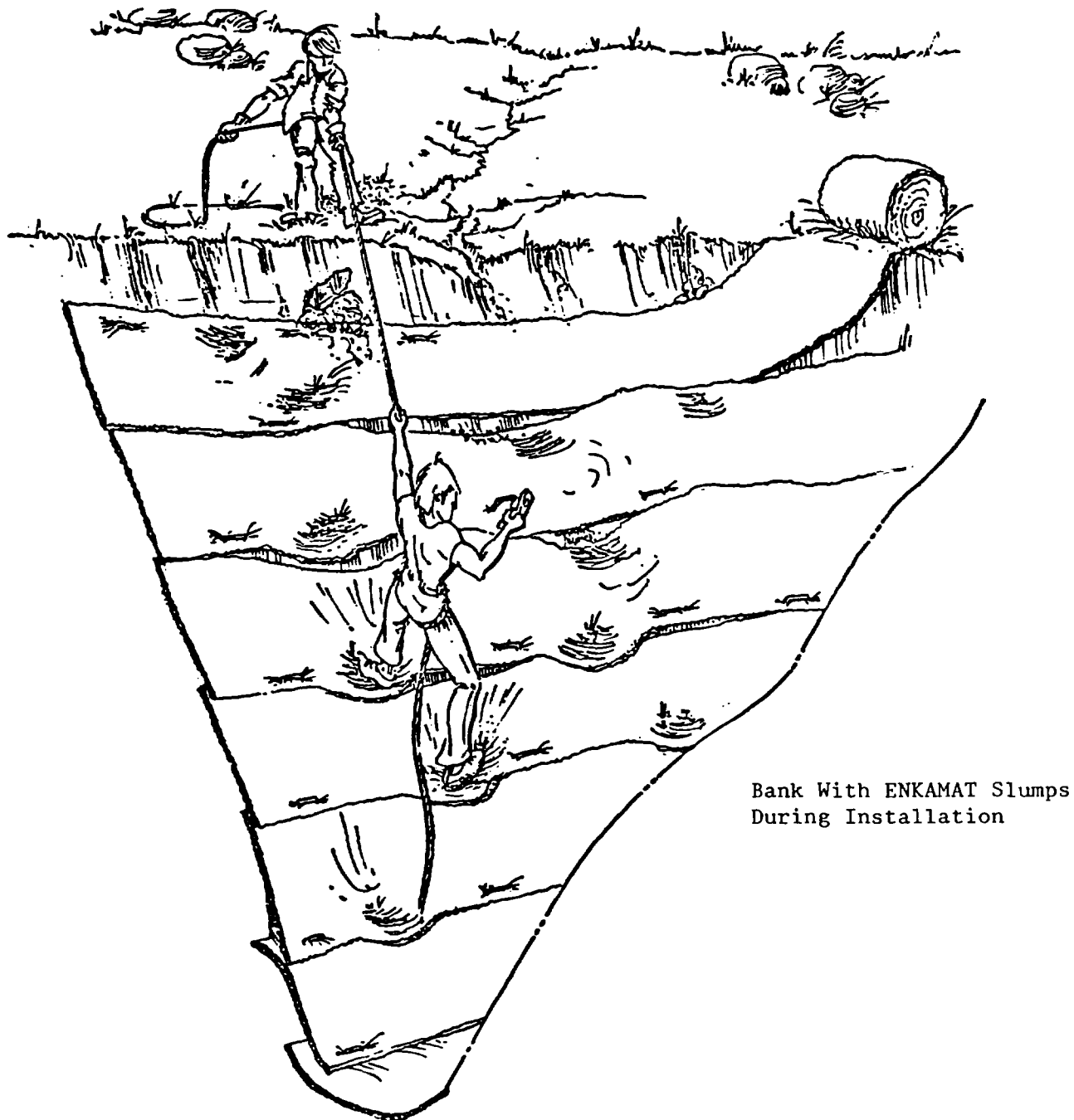
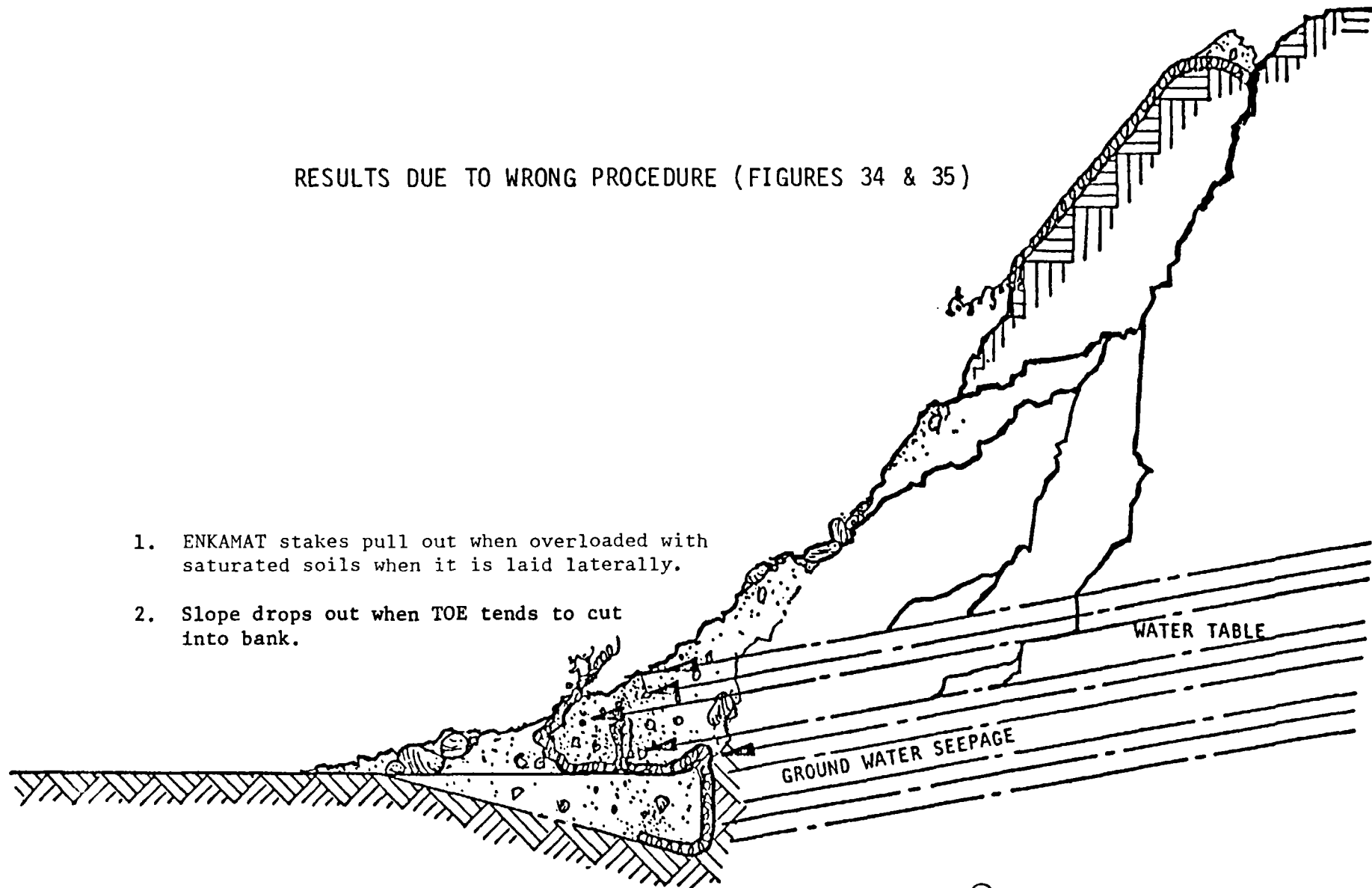


FIGURE 36 - INSTALLING ENKAMAT® ON BANKS

RESULTS DUE TO WRONG PROCEDURE (FIGURES 34 & 35)

1. ENKAMAT stakes pull out when overloaded with saturated soils when it is laid laterally.
2. Slope drops out when TOE tends to cut into bank.



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C. Seeding

1. It is recommended that the ENKAMAT® be installed prior to seeding in order to retain good seed distribution and avoid disturbance by work crews. On some occasions, it may be more practical to seed prior to installation; for instance, when overall project seeding operations are proceeding faster than ENKAMAT installations. If this occurs, it is recommended that disturbed ENKAMAT areas be manually reseeded. In central and northern zones, Kentucky 31 seeding mixtures are usually used for erosion control. In southern areas, Bermuda mixtures are common. However, selection of vegetation types is better left to the experts with which most agencies are well staffed. If recommendations are required, it is suggested that local SCS branches be referred to.

2. Hydromulching

Where hydromulching adjacent to areas covered with ENKAMAT is called for, it may be done either before or after installation. If mulch (containing seed) is disturbed under ENKAMAT, manual reseedling is recommended.

SECTION IV

APPENDIX

Items in this appendix, although not considered to be an integral part of the instruction manual, are included as background to familiarize sales personnel with nomenclature and design in approaches common to erosion control practices. It is felt that this information will also be beneficial as a quick reference to the design engineer.

A. TECHNICAL BACKGROUND INFORMATION

1. OPEN CHANNEL CROSS SECTIONS (FIGURE A-1)

Three basic cross sections are commonly used for surface water drainage. Modifications to these are indicated by dashed lines. These are usually made to facilitate construction and/or to define channel centers.

a. Parabolic

Common Usage: Highway median channels, agricultural land drainage channels, divergence channels, input and output extensions of natural swales

Anticipated Water Flow: Moderate velocities and/or volumes

Typical Side Slopes: 4:1 or shallower

Remarks: Accessible for vehicle crossover

b. Trapezoidal

Common Usage: Roadside channels, storm channels

Anticipated Water Flow: High volumes and/or velocities

Typical Side Slopes: 3:1-1:1 (Steeper side slopes are not recommended.)

Remarks: Bottom occasionally modified to a shallow V-shape in order to define channel center (see dashed line modification, Figure A-2-b)

c. Triangular (V-Shape)

Common Usage: Roadside divergence channels

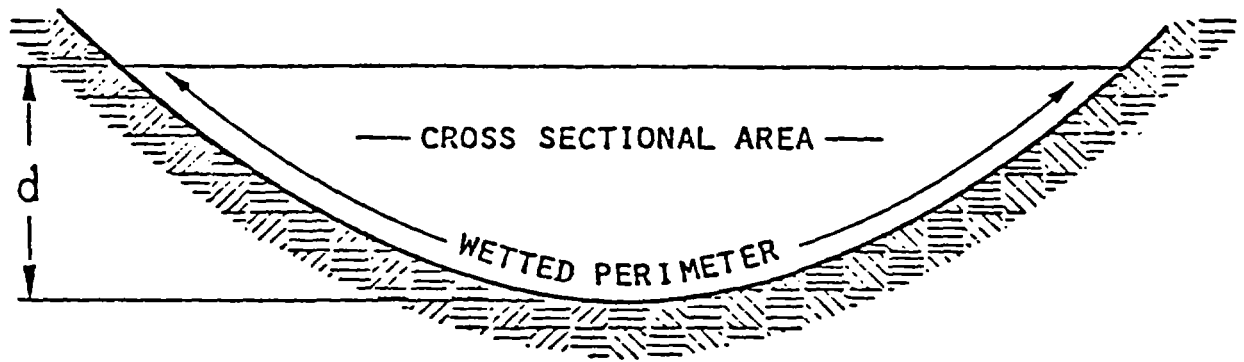
Anticipated Water Flow: Low volume, low velocity

Typical Side Slopes: 3:1 or shallower

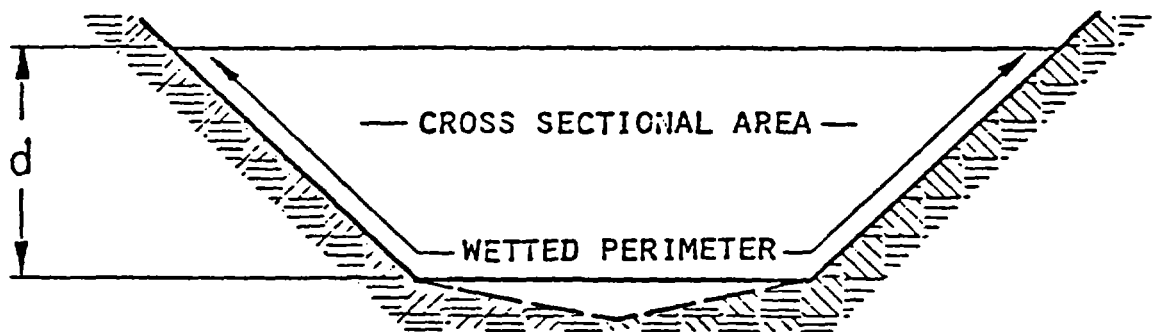
Remarks:

1. Occasionally modified to a rounded bottom (dashed line in Figure A-2-c)
2. Sometimes called J-shaped if backslope is extension of hillside
3. Accessible for vehicle crossover

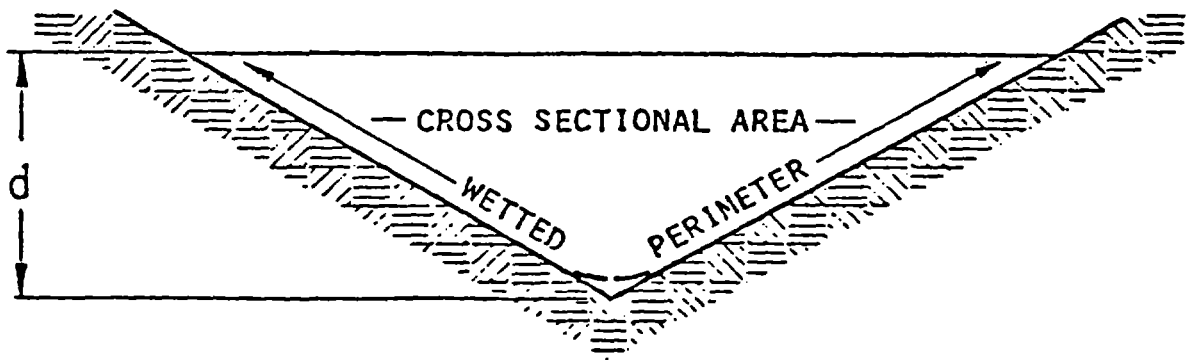
FIGURE A-1 - SCHEMATIC DIAGRAMS OF TYPICAL CHANNEL SHAPES



(a) PARABOLIC



(b) TRAPEZOIDAL



(c) TRIANGULAR

2. THE MANNING EQUATION

To determine channel capabilities for carrying off predetermined water volume, the following equations are commonly applied. However, since some of the variants are rather nebulous and published energy dissipation values of (η), at best, being rough approximations, it behooves the design engineer to use his best judgment in applying them.

The generalized Manning equation:

Equation A:
$$V = \frac{1.49 R^{2/3} S^{1/2}}{\eta}$$

Where: V = Average water velocity (f/s)
 R = Hydraulic radius (f)
 S = Hydraulic gradient (f/f)
 η = Coefficient of roughness factor

Equation B: Hydraulic Radius
$$R = A/W.P.$$

Where: A = Cross sectional area
 $W.P.$ = Wetted perimeter

Equation C: Carrying Capacity
$$Q = AV$$

Where: Q = Carrying capacity of channel (cf/s)
 A = Cross sectional area (f^2)
 V = Average water velocity (f/s)

3. GLOSSARY

Related terminology and definitions (refer to above equations and schematics of channel cross section shapes (Figures A-2).

- a. Depth (d): Depth of water in center of channel.
- b. Cross Sectional Area (A): The area of channel cross section enclosed by the perimeter at water depth (d).
- c. Side Slopes (S:S): The ratio of the horizontal distance for each foot of vertical drop on the submerged channel bank; i.e., the steepness of the submerged channel banks.
- d. Wetted Perimeter (W.P.): That portion of the perimeter which is submerged at depth (d); i.e., length of submerged side slopes plus width of channel bottom.
- e. Hydraulic Radius (R): Defined as the cross sectional area (A) of channel divided by the wetted perimeter (W.P.).
- f. Hydraulic Gradient (S): The longitudinal grade of the channel at the water surface of depth (d). Since the gradient at the water surface generally runs parallel to that of the channel bottom, the latter may be used to represent the channel gradient. (S) is the ratio of vertical drop per 100' of horizontal distance in the channel expressed in percent (%); i.e., if you get a 1' drop along a 10' foot horizontal length of channel, $S = 1/10 \times 100 = 10\%$ hydraulic gradient.
- g. Capacity (Q): The ability of the channel to carry a pre-determined volume of water at velocity (V) through a channel of designed cross section (A) (Equation C).
- h. Velocity (V): Means velocity of water flowing through a channel. It is primarily determined by the hydraulic gradient (S) and coefficient of retardance (η). It is, of course, affected by channel design which must be such that anticipated water volumes can be carried off at suitable velocity levels not to exceed permissible maxima for a given channel lining.
- i. Coefficient of Retardance (η) [sometimes called coefficient of roughness wherein it is related to the roughness of a channel lining]: It is a value denoting the ability of a channel lining to dissipate the water energy, thus retarding its flow velocity. At best, value of (η) is based on a rough estimate, and the design engineer must use his best judgment when selecting it from published tables.

The value of (η) is determined, not only by the roughness of the channel lining (for example, the height and type of vegetative growth) but also by the depth of water flowing through this vegetation.

4 " η " Values

As previously mentioned, the retardance factor " η " in the Manning equation is difficult to establish and, at best, is a rough approximation or "guesstimate" except for special idealized channel conditions.

However, there is no implication that this value is not useful. Although estimated " η " values are shown (Table A-1), it is stressed that the engineer should approach his channel design for vegetated growth when using an ENKAMAT® lining.

TABLE A-1 - "n" VALUES

(Estimated for Various ENKAMAT® Channel Lining Conditions at S = 5%)

Not Vegetated		Vegetated				
Condition	"n"	Vegetation	Ret.	Water Depth (Inches)		
				2-4	5-7	8-12
Bare	0.035 - 0.045	Short Growth	D	0.10 - 0.15	0.035 - 0.05	0.03 - 0.04
Silt (Partial)	0.025 - 0.035	Medium Growth	C	0.25 - 0.35	0.04 - 0.06	0.03 - 0.04
Silt (Full)	0.015 - 0.025	High Growth	B	0.35 - 0.40	0.05 - 0.10	0.04 - 0.05

B. Performance Data

For design purposes, ENKAMAT® channels should be treated as vegetated channels. However, where standard vegetated channels are restricted to limited design maxima, such as water depths and velocities, these restrictions are not applicable to ENKAMAT-lined channels.

The following tables indicate the field performance of channels lined with the ENKAMAT root reinforcing matrix. Authoritative sites and results are indicated, measured, and/or calculated results are denoted (Tables A-2, A-3).

It is pointed out that the depths and velocities shown in the ENKAMAT Systems are those experienced thus far in the field. They are not achievable upper limits.

1. ENKAMAT® CHANNELS

TABLE A-2
PERFORMANCE DATA - EM CHANNELS

<u>SITE</u>	<u>NORTH DAKOTA DOT</u>	<u>PENNSYLVANIA DOT</u>
Slope ($S_o = \%$)	3.4	22.5
Depth (ft)	1.0	0.4 0.5

Velocities (Ft/Sec) Calculated for Constant Depth
(Not Vegetated)

<u>ENKAMAT Condition</u>	<u>Estimated "n" Value</u>		
Bare	0.04	6	8 9
Silt (Partial)	0.03	8	11 12
Silt (Full)	0.02	12	16 18

<u>Received From Authorities</u>	<u>Computed</u>	<u>Measured</u>
Depth (ft)	0.8	?
Velocity (f/s)	7.8 (n = ?)	10 (n = 0.04)

1. ENKAMAT® CHANNELS - continued

TABLE A-3
PERFORMANCE DATA - EM CHANNEL (PENNSYLVANIA DOT)
(Flood Conditions)

<u>Channel Lining</u>	<u>"n"</u>	<u>DETERMINATIONS</u>	
		<u>Pennsylvania DOT</u> <u>V = F/S</u>	<u>AKZO</u> <u>V = F/S</u>
Concrete (c)	.02	30	33 (c)
Gravel (c)	.03	14	18 (c @ .02)
Fabric (Bare) (m)	.04	10	9 (m)
Vegetated (RRS) (c)	.05	8	8 (c)

(m) - Measured results

(c) - Calculations based on water flow relationships

3. Benefits Derived With the ENKAMAT® Root Reinforcing Matrix

Qualitative Comparison - Vegetative Versus Rigid Systems

Vegetated

Rigid (Concrete)

Advantages

1. Less Expensive
2. Less Hazardous to Traffic
3. Self-Healing Qualities
4. Low Maintenance
5. Filtration (In and Out)
6. Aesthetics (Natural Appearance)
7. Filtration of Runoff Particulate

1. Smooth Surface for Higher Flow Volumes and Velocities
2. Permissible for High Slopes
3. Unlimited Depth
4. Protects Underlying Soil

Disadvantages

1. Limited Flow Volumes and Velocities
2. Limited Channel Grades
3. Limited Depth Capacity for Given Cross Section
4. Inability to Establish Vegetation in Poor Soils

1. Expensive
2. Unnatural Appearance
3. Prevents Natural Infiltration and Exfiltration (Susceptible to Back Pressure Buildup)
4. High Velocities Create Scour at Output End
5. Susceptible to Edge Scouring and Undercutting

Channels reinforced with an ENKAMAT liner have all the advantages of the vegetated channel with minimal problems. They also have all the advantages of the rigid systems (except unlimited flow depth) and none of its disadvantages.